SAE journal

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JANUARY 1957

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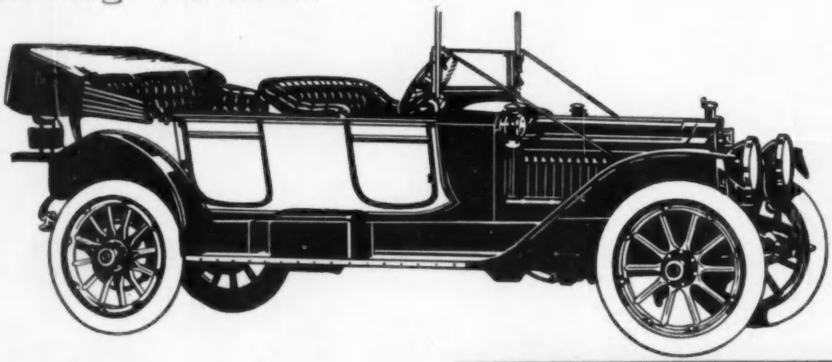
WHEN COMPRESSION RATIOS WERE 3 to 1...

any good oil ring would do!

1912 Packard with left drive control, electric self-starter, electric lighting. Starting, ignition and carburetor controls on steering column. Rated horsepower—38. Maximum brake horsepower—60. Engine—6 cylinders with bore of 4", stroke of 5½". A great car in its day!



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Best for new engines... essential for worn engines

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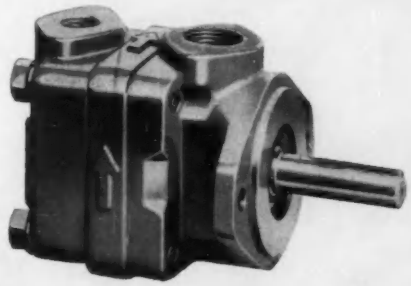
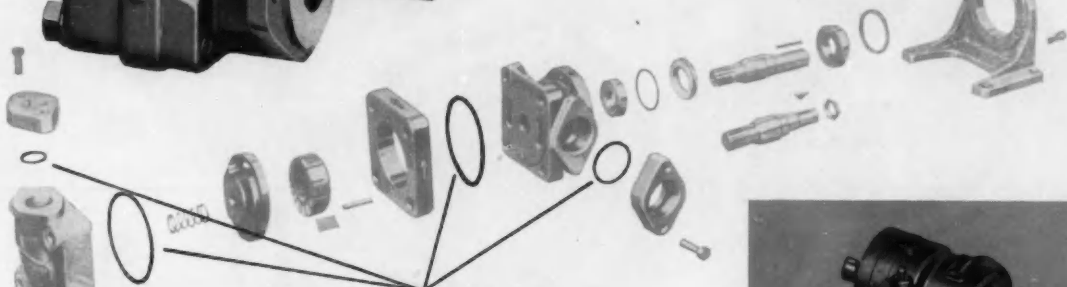
Precision "O" Rings protect the Heart of Hydraulic Power Steering Systems.



Precision "O" Rings provide positive hydraulic oil seal in this 1500 P.S.I. Mobile pump in a temperature range up to 160°F. Quality control in "O" Ring manufacture protects this heart of a power steering system.



There can be no compromise on quality and reliability in hydraulic power steering pumps. VICKERS Incorporated, of Detroit, Mich., the world's largest manufacturer of fine hydraulic pumps, use Precision "O" Rings to assure dependable, long life performance under exacting conditions.

Precision "O" Rings are used in the majority of VICKERS mobile and industrial hydraulic pumps. For VICKERS Incorporated and hundreds of other manufacturers, the use of Precision "O" Rings means economical, efficient, leak-proof operation.

Precision compression molded "O" Rings are rigidly inspected–quality-controlled–meet all military and commercial specifications–the finest made! Precision can furnish the size and compound that fits your product requirements.

Place your sealing problem in the hands of an expert–the Precision engineer. He can assist you in product design. Rely on Precision, the world's largest exclusive producer of "O" Rings.

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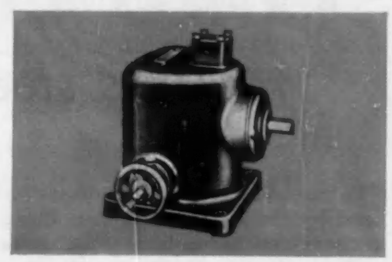

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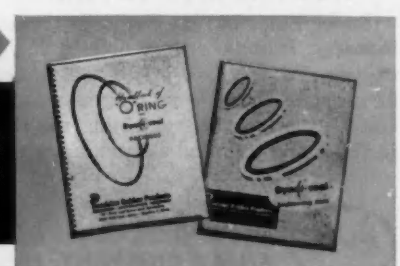

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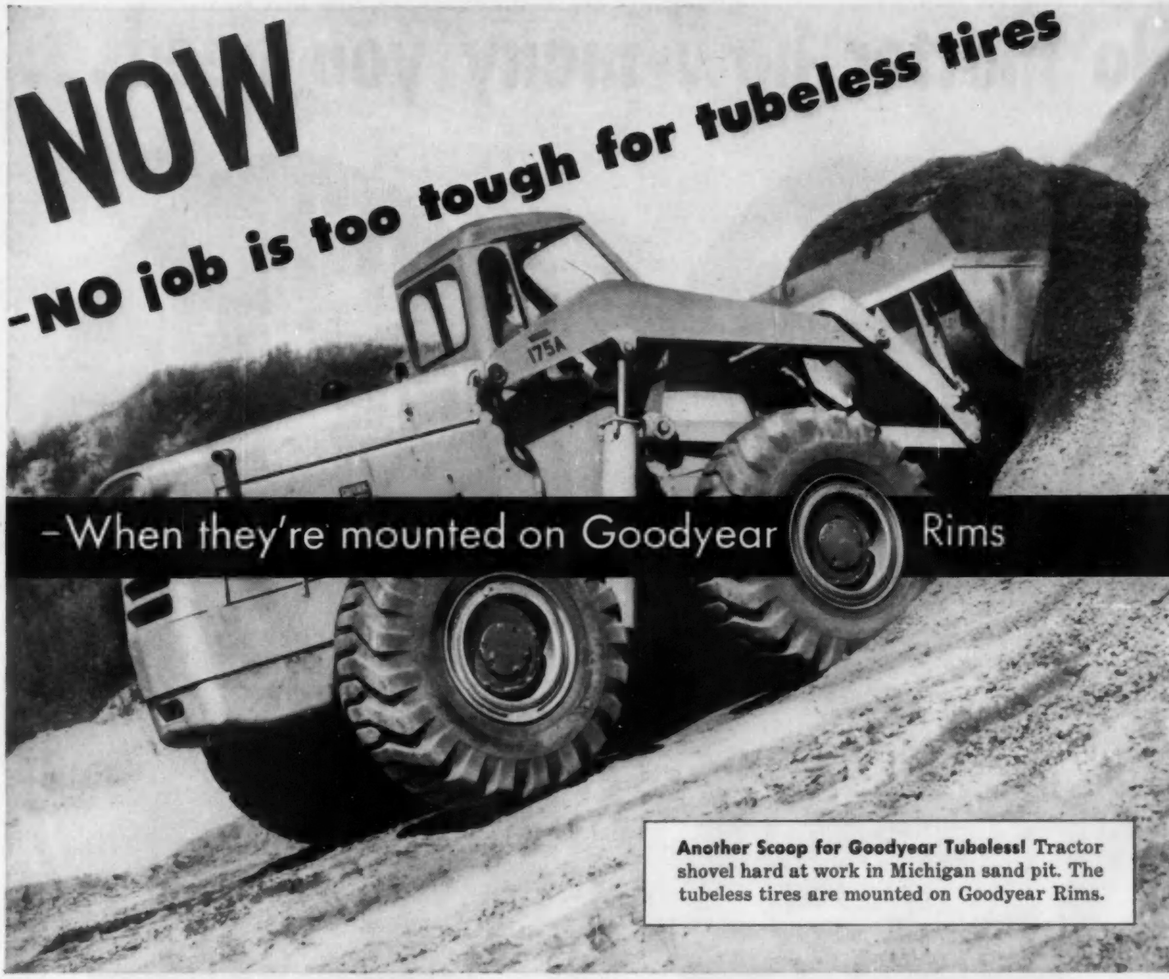

Another Scoop for Goodyear Tubeless! Tractor shovel hard at work in Michigan sand pit. The tubeless tires are mounted on Goodyear Rims.

Here you see just a sample of the tough jobs tubeless tires are doing – in today's mammoth construction projects. How did tubeless tires get into this picture—and so successfully, too?

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Bond-a-Coat Finish: This protective coating affords long-lasting resistance to rust and corrosion.

Got a Truck Rim Problem? GOODYEAR will solve it.

If you have a rim problem, why not talk it over with the G. R. E. (Goodyear Rim Engineer). He'll save you time and money by helping you select the type and size of rim best suited to your needs. Write him at Goodyear, Metal Products Division, Akron 16, Ohio, or contact your local Goodyear Rim Distributor.

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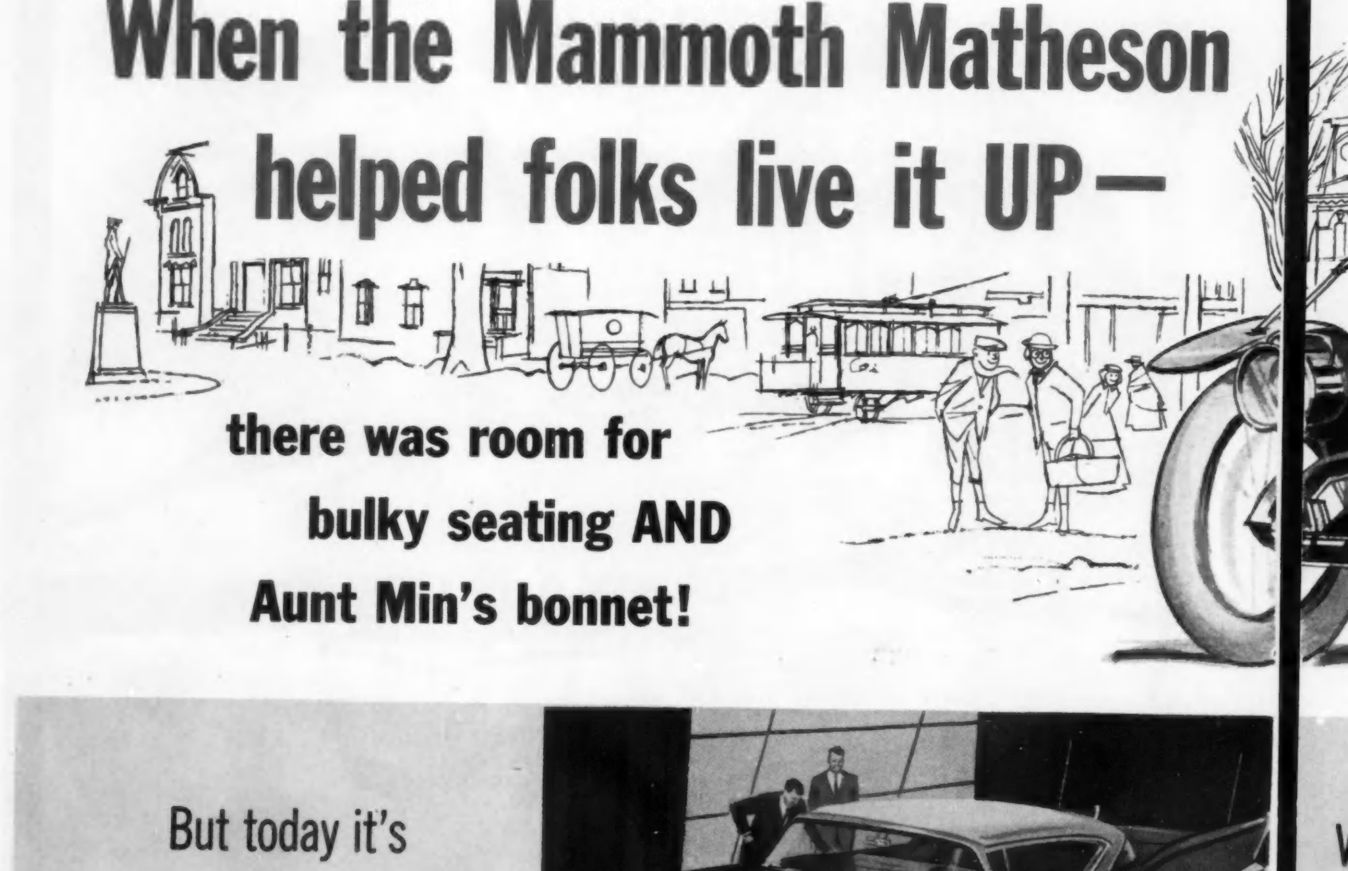
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there was room for
bulky seating AND
Aunt Min's bonnet!
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For the Sake of Argument

Pride in Action . . .

by Norman G. Shidle

An old Chinese proverb we thought up just the other day runs like this:

"Do something you are proud of—and you won't have to try so hard to be proud of what you do."

This means thinking and deciding before we act . . . thus reducing time spent afterwards trying to rationalize what we already have done.

To act with conviction is the only sure path to satisfaction. So conviction must be present before we act. And the conviction has to be within ourselves.

However wide our communication with others on the way to the conviction, the final "feeling" has to be our own, uncommunicable to anyone else. Without that personal, inner conviction, we get satisfaction from what we do only by chance.

Satisfactions are sparse when we act only with our heads . . . or only with our hearts. They are even sparser, when we act on our emotions . . . or when we make decisions by averaging conflicting opinions and data. The one condition that never really exists is the average condition. The one man who never lived is the average man.

Emerson once said that if a tiny straw were held in the right direction, the great Gulf Stream could flow through it.

Self respect, self-integration, and self-decision are essential elements to satisfaction with one's own actions. The effort needed to attain them is likely to be less when the "tiny straw" has been pointed in advance. Subsequent rationalizing tends to be both painful and profitless.

SAE journal

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Contents—JANUARY, 1957

THE CASE FOR POWER STEERING ON TRUCKS!

The trend to power steering on trucks is based on one very practical reason—operators of trucks equipped with power steering have invariably found that the added safety and greater operating efficiency of their vehicles have demonstrated that power steering is indeed a sound investment.

Truck drivers using power steering report less tension and fatigue in normal driving and appreciate the positive control that blocks road shock from chuck holes and prevents loss of control if the truck is forced out on a soft shoulder.

The dispatcher knows the importance of regularly maintained schedules. He is quite aware that with power steering drivers are more relaxed and are better drivers than tired drivers. Thus, power steering not only reduces the hazard of road accidents, but helps the driver to maintain established schedules through better vehicle control.

In short, power steering, by saving time and money, contributes materially to a more profitable operation.

Truck manufacturers are always eager to offer their customers features that will make truck operation safer and more profitable and, at the same time, give their dealers every selling advantage.

That's why more and more truck manufacturers are offering performance-proven Bendix* Power Steering as original factory equipment.

If you would like to know why power steering for trucks is perhaps even more logical than power steering for passenger cars, we have prepared an interesting folder on the subject.

Write for your copy today. We think you'll be convinced.

*REG. U.S. PAT. OFF.

Bendix PRODUCTS DIVISION South Bend IND.

Bendix AVIATION CORPORATION

Higher-Level Multi-Purpose Oils on the Horizon at the Start of 1957

THIS article is based on two recent statements on this vital-to-all-automotive-engineers topics by Chrysler's C. M. Heinen and R. E. Streets of the Department of the Army.

Both talked at the SAE National Fuels & Lubricants Meeting in Tulsa last October.

Heinen, who is also chairman of SAE's Fuels & Lubricants Technical Committee, titled his paper, "New Developments in Gear Lubricants." Streets' paper was "Performance Testing of Gear Lubricants in Military Equipment." Streets included in his paper specific data and conclusions resulting from full-scale field and laboratory tests carried out by the Ordnance Corps for several years.

Each paper is available in full in multilith form from SAE Special Publications. Price: 35¢ each paper to members; 60¢ each paper to nonmembers.

DEFINITE progress is being made toward a higher-level, multi-purpose gear lubricant to meet the increasing conflicting requirements of passenger cars and trucks (both civilian and military). Army Ordnance wants the military specification to conform to what is available in the civilian market—to simplify its supply problem. To that end it has made available recent tests on both passenger cars and military trucks from its efforts to establish the current requirements for military use.

Automobile and truck engineers, concurrently, have been working with petroleum engineers to establish new laboratory tests which will define the more severe levels of operation . . . and this work has proceeded rather well.

The major existing problem is to define quantitatively the present and future requirements . . . to set the severity levels; then to find the oils needed by way of newly modified test techniques.

Current multi-purpose gear oils, civilian and military interests concur, do not have enough chemical activity to supply the necessary chemical films under all the new peak torque conditions. (Higher engine loads, slightly higher car weights, and low bodies with resultant static gear sizes all combine to increase gear loads which may result in scoring. Only the trend toward lower rear axle ratios helps to alleviate this problem.)

Introduction of additives to increase the oil's ability to prevent scoring has, in some instances, made

them less capable of operating under high temperatures without producing corrosion or excessive deposits.

All of the criteria for successful lubricant performance, in other words, must be faced and incorporated in the sought-for new higher level multipurpose gear oil. These criteria include ability to:

- Reduce failure of gear-tooth surface by scoring, ridging, or excessive wear;
- Reduce corrosion and pitting fatigue of gears due to excessive activity;
- Reduce bearing failures due to formation of excessive deposits and high-temperature conditions; and
- Maintain thermal and oxidation stability.

Everybody agrees such a higher-level, multi-purpose gear oil is needed. But there is little agreement on the specifications which such an oil should have. To some extent, of course, everybody is guessing. And current guesses range all the way from present multi-purpose oils to those which would meet the most difficult operating conditions which might be devised.

Trying to come closer to specific definitions, the problem falls logically into three phases:

1. To determine, in some absolute terms, what level of performance the present tests are defining;
2. To establish several ranges of test severity which would describe all existing oils and allow a range for oil improvements; and
3. To find out where in the range of test severity an oil must fall to meet present requirements.

Progress is being made on each of these three steps. The work is partly a combination of the individual efforts of vehicle, petroleum and military engineers . . . and partly their joint efforts in cooperative attacks on the problem.

One step in this progress is realization that the L-19 and L-20 tests leave something to be desired in the way of reproducibility . . . and in improving the L-20 condition by closer control of the test gears.

Improved reproducibility is being sought in L-19 by closer attention to a variety of causes which tend to reduce accuracy.

Strain of age measurements will make available the first quantitative information on severity of the L-19 test. (Similar measurements are being made on the L-20. But there the problem is less difficult, since no change in loading is called for during the operation.)

The previously mentioned test results contributed by the Army Ordnance group have shown reasonably good correlation with a proposed L-37 test . . . upon which agreement has nearly been reached by the vehicle and petroleum engineers concerned.

Vehicle manufacturers are engaged in extensive tests looking to establishment of a severity level for present and future requirements for high-speed, shock-load resistance. This would seem to be prerequisite to definition of oils to meet present and future requirements . . . both in this respect and also for truck operation.

Where the new severity level will be established is anybody's guess as 1957 begins. Some think it might be around 12, the level of active sulfur. Others, who have phosphate-treated their gears, think a level of around 8 may be adequate. In any case, this future satisfactory multi-purpose oil is going to have a level considerably higher than the existing 5–6.

Before these considerably higher level oils can actually be made available at retail, several marketing problems must be met, even after all the technical problems are pretty well solved.

If the new high-level lubricant had excessive sulfur activity, for example, it would not be satisfactory for truck operation. Yet many trucks come for lubrication to the same stations which service passenger cars. So, those stations would have to carry two lubricants. That would mean higher costs.

Moreover, it could mean additional confusion. Already fear of confusion at the retail service level has caused manufacturers representing 70% of passenger car production to ask that "no change" be made from the factory fill . . . and they have removed the drain-plug to reinforce the "suggestion."

There are, in general, however, several favorable aspects to the gear-oil situation as it appears at the beginning of 1957. While the requirements for gear lubricants have increased, test procedures for establishing the new level are proceeding satisfactorily. . . . A new level for multi-purpose gear oil is needed to prevent confusion in the civilian market and to meet the needs of the military . . . but suitable oils are available.

Bolt Trouble?

■ *If you are having trouble with a bolted joint due to loosening, thread stripping, or failure by fatigue:*

1. *Preload the bolt by tightening the nut to yield strength of the bolt.*
2. *Use SAE grade 8 nuts and bolts. (Heat treated to Rc 32–38 min. T.S. = 150,000 psi.)*
3. *Use SAE UNC Class 2A and Class 2B Thread.*
4. *If possible use higher strength abutments. If not, use large, thick, heat treated flat washers to increase its effective stiffness.*
5. *If the abutment is not too thin and it is not a gasket joint, throw away the lock washers.*

—E. J. Eckert

Nonspinning Differential Gives Increased Traction

Forest McFarland* and E. L. Nash

Studebaker-Packard Corp.

Based on paper "The Packard Nonspinning Differential" presented before SAE Colorado and Salt Lake City Groups, May, 1956.

DESIGN of the Packard nonspinning differential (Fig. 1) is aimed chiefly at reducing the traction and directional stability deficiencies of the standard differential. Its construction gives a locking action which provides better traction under difficult driving conditions. Hence, a car with a nonspinning differential no longer depends upon each wheel having the traction necessary to enable the other wheel to drive the car.

With this nonspinning differential the maximum torque available on one wheel can be up to five times that of the other wheel due to its traction, unlike standard differentials which have torque on one wheel almost equal to torque due to traction of the other wheel. With this increased torque bias driving can be made easier where conditions are considered hazardous.

The nonspinning differential differs from the standard ones in the following points:

1. The side bevel gears carry encompassing cones which fit into internal cones in the differential case. These cones take the axial thrust of the side gears which is ordinarily taken by thrust washers behind the gears. The loading on the cones, together with the normal thrust of the gears, will tend to lock the side gears to the differential case, preventing individual spinning of either wheel.

2. Both pairs of pinions are carried on individual shafts bearing flats at 30-deg to plane of rotation of the differential which match the 30-deg cams cut in the differential case. Each pinion has a cylindrical shoulder just above the teeth at the large end of the pinion. This shoulder contacts the flat, circular face of the clutch cone of the side gears.

3. The drive is transmitted from the engine by the propeller shaft to the rear-axle driving pinion and ring gear, and thence to the differential case. The drive is then transmitted by the 30-deg flats on the differential case against the mating flats on the pinion shafts. This results in the driving force being applied by the four pinions to both side gears which are splined to the respective rear-axle shafts. Some pressure is applied against the cones by the pinion teeth operating at a 22½-deg pressure angle. The main pressure is obtained from the pins wedging against the differential case flats. This causes the round diameter integral with the pinions to bear against the flat surfaces of the gear cones. These flats are 180-deg apart for one shaft and likewise for the other shaft, which is 90-deg from the first shaft. One shaft operates against one side-gear cone and the other shaft against the other side-gear cone. The pins are notched to avoid interference with each other and to permit individual movement of the shafts under load.

(For complete paper in multilith form on which this abridgment is based, write SAE Special Publications, 485 Lexington Ave., New York 17, N. Y. Price: 35¢ to members, 60¢ to nonmembers.)

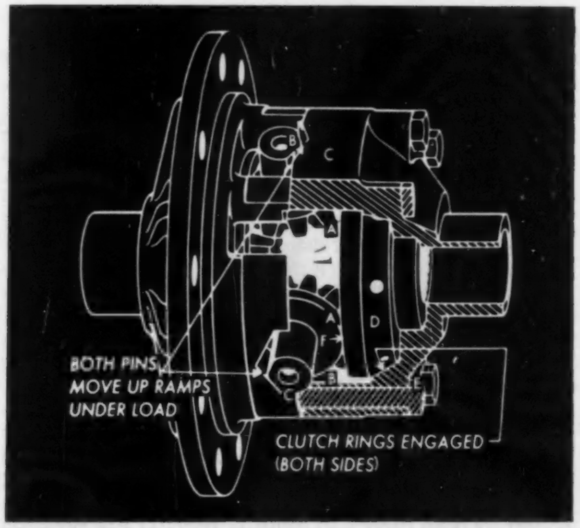


Fig. 1—General design of Packard Twin Traction unit. It is built to increase traction, thereby providing greater torque bias than in standard differential.

* Now with Buick Motor Division, GMC.

Door Opens to

75 lb Aluminum

Successful development of a 43-lb, 6-cyl engine block as a one-piece aluminum die casting leads the way. . . . Before long: a 70 lb, V-8 block.

SUCCESSFUL development of a 43 lb, 6-cyl engine block as a one-piece die casting opens the door on large aluminum die castings for the automotive industry. The previous limit of 20 lb maximum weight has been overcome by development of a die-casting machine capable of handling aluminum die-castings up to 75 lb . . . and the price differential between aluminum and cast-iron is more than compensated by application of modern die-casting which converts molten aluminum into a highly finished casting in one operation.

First Die-Cast 6-cyl Engine Block

This 43 lb, 6-cyl engine block (which started out to be a 4-cyl, 28 lb block) was designed to be produced as a biggest-to-date aluminum die casting at the same time the new biggest-to-date die-casting machine was being designed to handle it. The concurrent designs were undertaken in 1951 as a joint project between the Willow Run automotive plant of Kaiser Aluminum & Chemical Corp. and the Doehler-Jarvis Division, National Lead Co.

Both companies participated in design of the engine block; Doehler-Jarvis engineers did the job on the die-casting die.

To accomplish a block design suitable for die casting, three requirements had to be met in which die castings differ from sand castings:

1. *No undercuts:* (Fig. 1) All parts of a die-casting die are made from steel to withstand the impact of the injected metal. Sand cores cannot be used and other destructable materials which withstand the impact of the injected metal have not yet been found. Loose pieces to build undercuts are possible but must be ruled out as uneconomical. On the left side of the housing is shown a typical undercut and a loose piece arrangement. On the right side is shown how to overcome them.

2. *Avoid heavy sections and walls:* Heavy sections do not solidify as fast as thin sections. When metal shrinks while it solidifies, the thin sections draw metal from the heavier sections which are still molten. Since risers cannot be applied on die castings, shrinks appear in heavy sections as shown in Fig. 2.

3. *Design all holes to be cored:* Not only to save

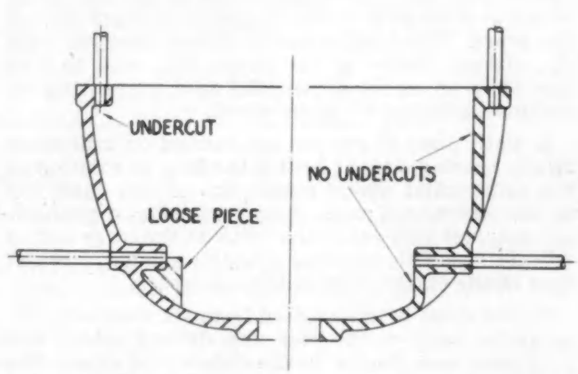


Fig. 1—Undercuts . . . and methods to overcome them in die casting.

Die Castings

Alfred F. Bauer, Doehler-Jarvis Division, National Lead Co.

Based on paper "Six-Cylinder Engine Block in Aluminum Die Casting" presented at SAE Detroit Section Meeting, April, 1956.

machining cost and simplify equipment, but to produce as sound a casting as possible.

The 43 lb this 6-cyl engine block weighed as finally produced (Fig. 3) is about 130 lb lighter than gray iron. It contains 129 holes, all of which are cored. Thus, drilling operations are eliminated. Machining stock varies between 0.030 and 0.060 in. The wall thickness is most uniform and 5/32 in. thinner than in gray iron.

The three basic changes made to adapt the block to die casting are explained in Fig. 4.

THE WET SLEEVE ARRANGEMENT, necessary to form the pockets for water cooling, was the first. The six wet sleeves are pressed into the bores of the aluminum cylinder block and sealed with O-rings against the cooling water.

RELOCATION OF THE CAMSHAFT from the side of the engine block to the top of the cylinder head was the second basic change. With the camshaft at the side, it would have been difficult to core all

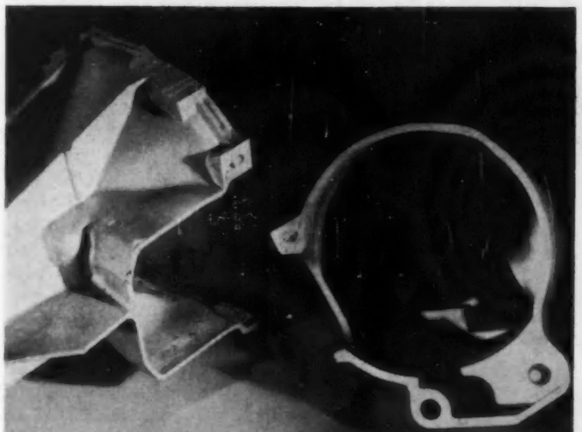


Fig. 2—Typical heavy sectinos where shrink holes appear.

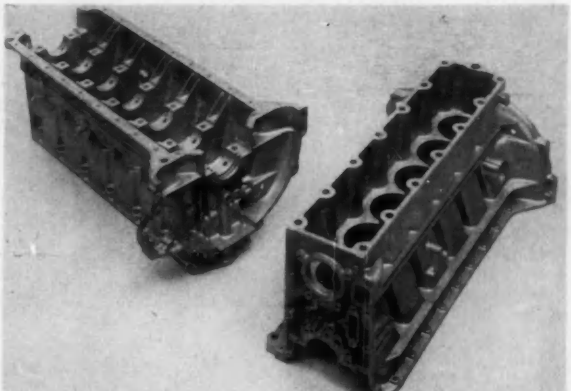


Fig. 3—6-cyl engine block in aluminum die casting. Weight 43 lb.

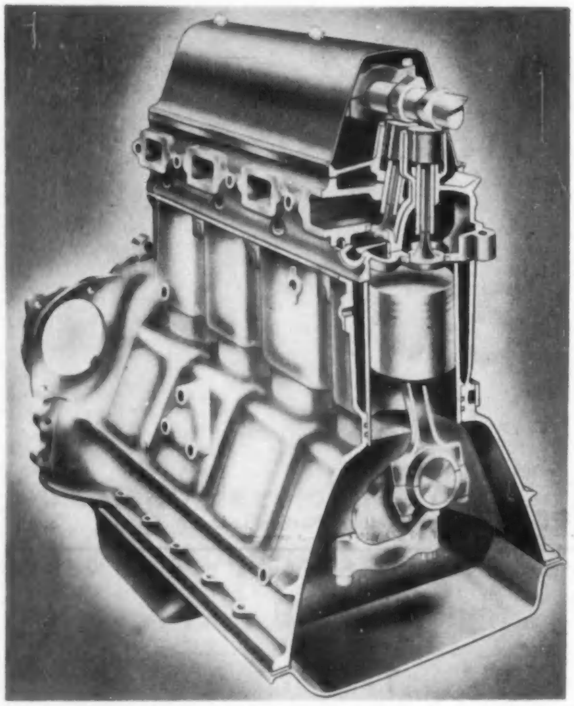


Fig. 4—Isometric drawing of Kaiser-Frazer engine block showing die-cast design with wet sleeves and camshaft in the cylinder head.

the holes in the seven walls of the camshaft bearings. This change brought much simplification in design, but resulted in some objections to the somewhat noisy chain drive and other complications.

DEEP POCKETS IN BOTH SIDES OF THE BLOCK, never before shown on a gray iron casting, comprise the third basic change. These pockets are actually metal-savers to eliminate heavy metal sections behind the main bearing (Fig. 5). Long oil holes for the main bearing connect these pockets with the oil channel which is cast as an open channel and closed and sealed by a cover.

Fig. 5—Cross sections through engine block show elimination of heavy walls behind main bearings.

The surface of these die-cast engine blocks is of unusual smoothness. Mis-match or shift is smaller than in any other casting method and often only a few thousands of one inch. For general dimensions the tolerances are held within ± 0.001 for each inch of length. Closer tolerances may be obtained by agreement with the die caster. (Reference is made to the Product Standards for die castings recently published by the American Die Casting Institute.)

All engine blocks produced in test runs were made from S-12-A with 12% silicon. This alloy was chosen as best suited in physical properties and in soundness. Other aluminum alloys such as SC84A and SC114A may also be used for engine blocks. Many of these engine blocks have been checked carefully and show a structure of unusual soundness. Leak tests revealed that most of the blocks tested were sound and leak proof as cast. The remaining parts had minor leaks which were sealed mostly mechanically. For large scale production the application of a simple impregnation method may be advisable.

The Engine Block Die

The die-casting die for these engine blocks presented almost as many problems as the die-casting machine.

With a total weight of 30 tons and a width of 84 in. across the parting line it is, of course, by far the heaviest and largest die-casting die ever built. It cost $150,000 and took 12 months to build. Contrary to past practice, the impression of the die is built from numerous small sections of die steel, cut and fit advantageously as shown in Fig. 6.

This was done because:

- The quality of small thoroughly forged blocks is better and more uniform than that of large ones;
- When the die starts to wear, small sections can be replaced;
- Changes on the die casting can easily be accomplished by correcting or replacing small segments rather than large expensive blocks;
- This construction eliminates the fear that the whole die might crack in two pieces and compel months of waiting before the huge piece is repaired.

Fig. 7 shows the cover die with a weight of 8 tons mounted into the die-casting machine. The molten metal is introduced through the cover die into the gate. Because of the tremendous size of this die the conventional heating of dies with torches from the outside was not sufficient. The die, therefore, shows an internal heating system through which the die is heated on outside sections while the inside sections are water cooled.

Fig. 8 shows the ejector half with all four core pulls in an opened position. The ejector half contains most of the cavity of the engine block. The four sides are built by four large side cores and locked in position with a total of 4,000,000 lb. The increase of the hydraulic pressure from 1200 to 3500 psi helped much to create the necessary locking pressure for these large core pulls.

On dies as large as this one, temperature control

of each part of the die is of prime importance to insure proper functioning of the moving parts of the die and to get uniformity of quality and dimensions. So, thermocouples and temperature controls are built into the cover die and the ejector die . . . also into the four main cores.

The gate through which the metal is forced into the die was carefully computed with formulas and figures based on many years of scientific research.

Advantages of Die-Cast Blocks

The biggest savings in comparison with gray iron blocks are possible through the inherent characteristics of the die-casting process to produce a highly finished casting in one single operation. Other advantages which aluminum die castings have to offer are:

1.—THINNER WALLS—It is an old habit to suggest an increase in wall thickness when a part is converted from iron to aluminum. Such an increase is definitely not justified in any conversion from gray iron to aluminum because the mechanical properties of gray iron are not higher than those of aluminum die-casting alloys. Fig. 9 shows the higher tensile strength and elongation of aluminum alloys in comparison with gray iron.

In addition, the walls of gray iron engine blocks are not designed for strength, but for the most eco-

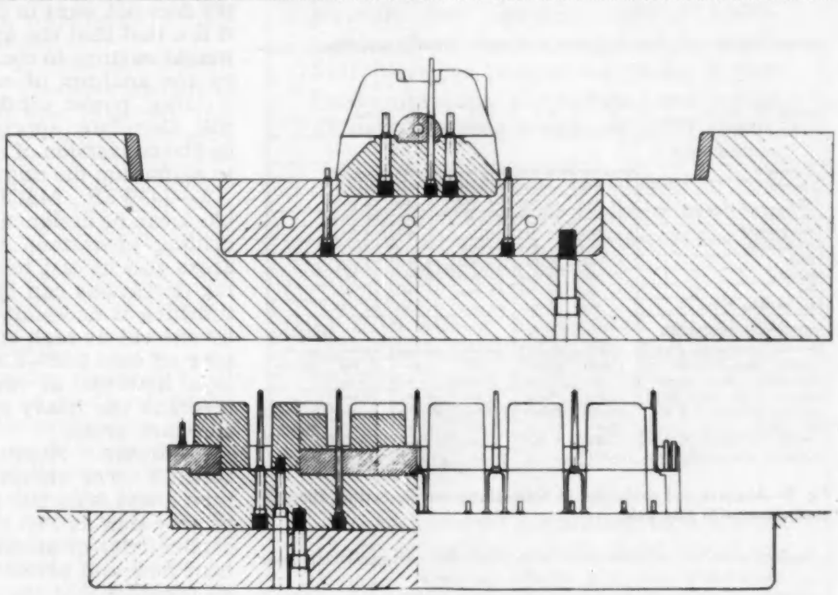


Fig. 6—Cross sections through cover die of engine block show numerous small sections of die steel, cut and fit advantageously to form the cavity.

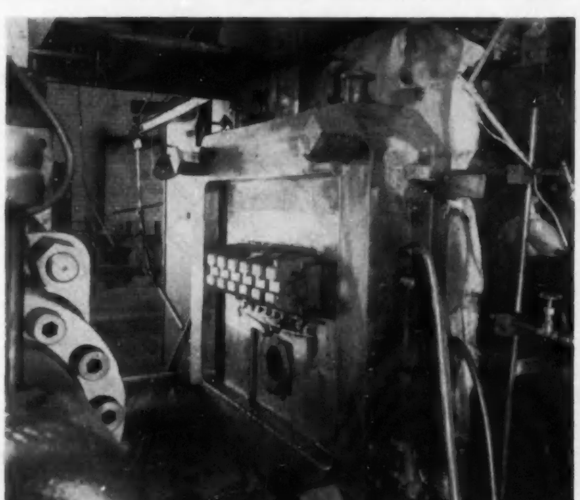


Fig. 7—Cover die of engine block in die-casting machine weighs 8 tons.

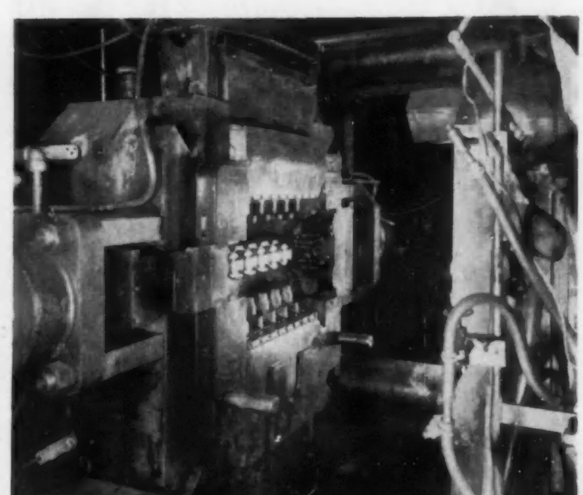


Fig. 8—Ejector die of engine block with side cores in open position.

nomical wall thickness of 0.200–0.250 in. In aluminum die casting we are taking full advantage of this and decrease the walls as far down as 0.100 in. where lower stresses allow this.

2.—NO CORE SHIFT ALLOWANCES—Gray iron with its sand molds has to take into account a certain misalignment and shift of cores. This allowance in walls and bosses is not necessary in die casting and can be subtracted from the walls, adding substantially to the weight savings.

3.—LESS MACHINING STOCK—The high accuracy and smoothness of aluminum die castings permit many areas to be cast without machining stock at all. Where finishing operations are necessary such as on sealing areas or in bearings, the machining stock of die castings can be held much smaller than in gray iron; 0.030–0.050 in. is mostly sufficient.

4.—LIGHTER WEIGHT—The combination of thinner walls, no core-shift, and less machining stock greatly decreases the weight and may result in a 1 to 4 weight advantage of an unmachined aluminum die-cast engine block over an unmachined iron block. While aluminum is only 2½ times lighter than gray iron, a properly designed engine block in aluminum die casting may weigh only ¼ as much as a raw gray iron block. The saving might run from 130 to 150 lb. This reduction in cast weight brings the cost of a die-cast aluminum cylinder block well within the competitive price of a raw gray iron block.

Furthermore, even though the automotive industry does not want to pay a premium for light weight it is a fact that the automotive engineer has to find weight savings to counteract the overweight caused by the addition of such new accessories as power steering, power window, air conditioning, etc. He will, therefore, appreciate the saving of 130–150 lb by the conversion of an engine block from gray iron to aluminum die casting.

5.—LOWER MACHINING COSTS—An engine block can be designed so that all holes are cored and drilling operations completely eliminated. Other areas may be cast to size and so smooth that finishing operations can be held to a minimum. Where finishing is necessary it can easily be accomplished by *one* cut at high speed because the tools have to take off only 0.030–0.040 in. machine stock. In gray iron, however, at least two cuts are necessary to machine the heavy stock of ⅛ in. and to take off the hard crust.

6.—MORE HORSEPOWER, HIGHER EFFICIENCY—The thermal conductivity of the aluminum alloys is on the average about three times that of gray iron as Fig. 10 shows. This higher thermal conductivity of aluminum results in a much faster heat flow and better cooling effect especially when we consider that the cylinder head also is of aluminum.

7.—NO COOLING RESTRICTIONS—With the wet sleeve arrangement and the accuracy and smoothness of aluminum die castings, the water channels

DOEHLER ALLOY	31	39	312	310	218	
A.S.T.M. No.	S12A	SC84A	SC114A	SG100A	G8A	
COMPOSITION %						
ALUMINUM	REMAINDER	REMAINDER	REMAINDER	REMAINDER	REMAINDER	
COPPER	0.6 MAX	3.0 to 4.0	3 to 4.5	0.6 MAX	0.2 MAX	
IRON	1.3 MAX	1.3 MAX	1.3 MAX	1.3 MAX	1.8 MAX	
SILICON	11.0 to 13.0	7.5 to 9.5	10.5 to 12	9.0 to 10.0	0.3 MAX	
MANGANESE	0.3 MAX	0.5 MAX	0.5	0.3 MAX	0.3 MAX	
MAGNESIUM	0.1 MAX	0.1 MAX	0.1 MAX	0.4 to 0.6	7.5 to 8.5	
ZINC	0.5 MAX	1.0 MAX	1.0 MAX	0.5 MAX	0.1 MAX	
NICKEL	0.5 MAX	0.5 MAX	0.5 MAX	0.5 MAX	0.1 MAX	
TIN	0.1 MAX	0.3 MAX	0.3 MAX	0.1 MAX	0.1 MAX	
ALL OTHERS TOTAL	0.2 MAX	0.5 MAX	0.5 MAX	0.2 MAX	0.2 MAX	
MECHANICAL PROPERTIES						S.A.E. 111 GRAY IRON
TENSILE STRENGTH P.S.I.	39,000	42,000	46,000	41,000	45,000	30,000
TENSILE YIELD STRENGTH P.S.I.	21,000	21,000	27,000	23,000	27,000	20,000
ELONGATION % in 2 INCHES	2.0	3.0	1.0	5.0	8.0	?
COMPRESSION YIELD P.S.I.	15,000	17,000	21,000	18,000	23,000	
SHEAR STRENGTH P.S.I.	25,000	27,000	29,000	26,000	28,000	41,000
ENDURANCE LIMIT P.S.I.	19,000	20,000	21,000	18,000	23,000	15,500
CHARPY IMPACT FT LBS.	2.0	3.5	2.0	4.2	6.3	
MODULUS of ELASTICITY P.S.I.	10.5×10^6	10.5×10^6	10.5×10^6	10.5×10^6	10.5×10^6	15×10^6

Fig. 9—Analyses and properties of some aluminum die-casting alloys in comparison with gray iron.

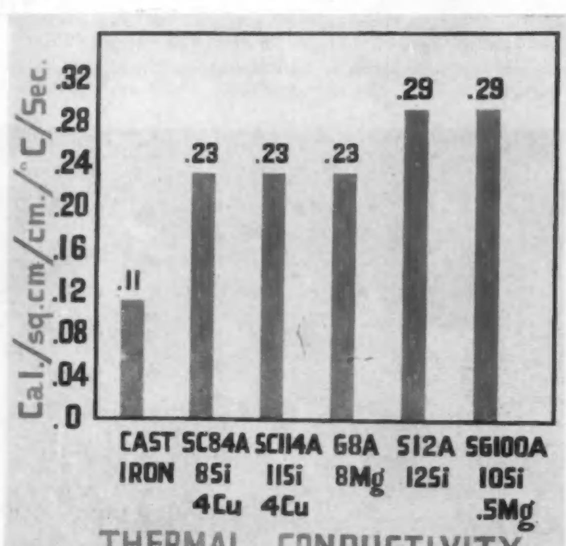


Fig. 10—Thermal conductivity of gray iron and aluminum alloys.

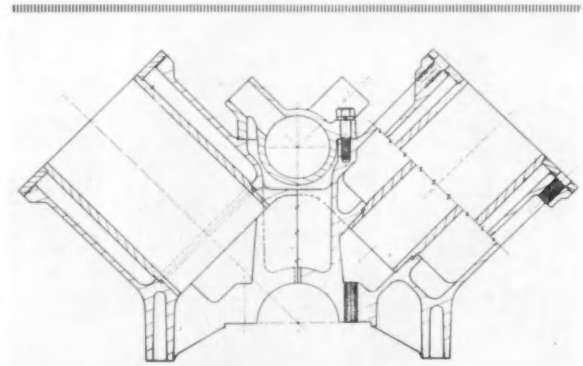


Fig. 11—V-8 engine block designed for aluminum die casting with wet sleeves in gray iron.

in a die cast engine block can be maintained absolutely uniform even if decreased to ⅛ in. width.

Many engines leaving the production lines have a low efficiency because of mislocated shifted sand cores, steam pockets or sand pockets. The accuracy and smoothness of the water cooling channels therefore must be valued as one of the biggest advantages of the die cast engine with wet sleeves.

8.—EASE OF HANDLING—The lighter blocks are easier to handle, to store and transport. The chips are light and clean, the operators and machines stay clean all day long, and there are few chips to be removed.

A V-8 Engine Block Soon

Work on a V-8 engine block is far enough advanced to predict that a design suitable for aluminum die casting will soon be available.

One of the possible solutions to a die-cast V-8 engine block is shown in Fig. 11. The big undercut in the center of the V-section has been eliminated by designing the camshaft bearings together with the valve lifter bearings as a separate die casting. The long oil holes through the block—usually on each side of the camshaft—which could not have been die cast, have been omitted and all undercuts eliminated. The main oil supply is accomplished through the channel built by the space between block and the separate die casting for the camshaft bearing.

Sleeve Arrangements

For the V-8 block we have chosen a different wet sleeve arrangement than that of the 6-cyl block. Centrifugally cast iron liners are brazed into a deck plate. The whole assembly is finish-bored and honed to size and then installed in the block. This can be done with little effort since the lower ends of the four sleeves on each side have a clearance fit with the bores. One synthetic rubber seal ring of square shape is used instead of two expensive O-rings shown in previous designs. This wet sleeve arrangement follows very much a design of the Perfect Circle Corp. with whom we have close contact in the wet liner design.

In our endeavor to decrease the overall costs for

MAGNESIUM READY FOR AIR-COOLED BLOCKS

In a complete paper from which this abridgment was made, the author points out that magnesium die castings (already as far developed as aluminum) would be ideal for engine blocks of air-cooled engines. Magnesium's extremely low specific weight (60% lighter than aluminum) and its excellent physical properties make it perfectly adaptable for engine parts *which do not come into contact with water.*

Its relatively low resistance to corrosion would create quite a problem were an attempt made to use it for water-cooled engine blocks.

With either magnesium or aluminum, he says, a properly designed air cooling system works just as well as water cooling for engines. It's the low conductivity of gray iron that doesn't permit air cooling.

A number of European cars are already using air-cooled, light-metal engines. Among them are the *Porsche* and the *Volkswagen.* Volkswagen uses some 30 lb of magnesium in its design.

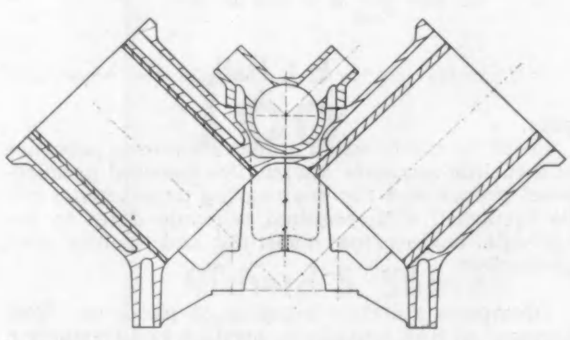


Fig. 12—V-8 engine design with gray-iron sleeves cast-in as inserts (2 versions).

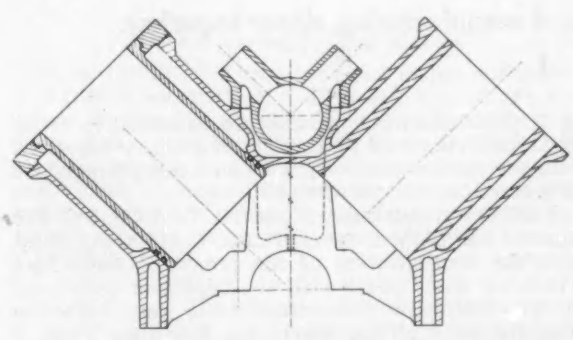


Fig. 13—All-aluminum V-8 engine without gray-iron liner. Right side: liner is integral part with blocks. Left side: extruded aluminum sleeve is cast-in as insert.

these liners, we have studied quite carefully the possibility of casting the sleeves in as inserts.

Two different versions of cast-in gray-iron sleeves in a V-8 engine are shown in Fig. 12. The sleeve on the right side is completely surrounded with aluminum following the design of the 2-cyl engine block of the outboard motor. On the left side only the lower portion of the sleeve is cast-in. There is a possibility of a leak in the mechanical bond, therefore, the design on the right is the preferable one. A disadvantage of both designs is that the sealing area between explosion chamber and water channel is relatively small.

The insertion of eight sleeves into the hot die-casting die every time before a shot is made will slow down the production and might result in other serious problems. It is, therefore, not likely that cast-in sleeves will be more economical than set-in sleeves. However, such a solution is technically possible and might be accomplished without too much delay in cycle time by the use of an automatic loading mechanism.

Without Iron Sleeves

Two versions of an all aluminum V-8 engine block (with gray-iron sleeves eliminated entirely) are shown in Fig. 13. The right side shows an engine block with the cylinder walls cast as an integral part of the block. From a die-cast standpoint this is possible, but such a design will add to the complexity of the castings. The biggest problem of this design will be to produce a perfect metal structure without porosity in the bores when the taper is removed in the final machining operations.

The left side shows an all aluminum design with extruded aluminum sleeves, bored and honed and chrome plated prior to assembly. The sleeves are pressed into an aluminum deck plate while their lower ends have a clearance fit with the bores. Two conventional O-rings in the sleeves provide a proper seal and allow the sleeve to expand freely without creating inner stresses or distortion of the block. The principle of the free floating sleeve with two O-rings can, of course, be adapted to gray iron sleeves also.

With the cylinder walls in aluminum, the bore has to be hard-chrome plated to insure better wear conditions.

Chromium has a great resistance to sulfuric acid formed during combustion. Moreover the chrome deposit is hard and has an extraordinarily low coefficient of friction. Since the lubricant remains in the finely cracked surface it is most wear resistant and, therefore, just about the most ideal material for this purpose.

The only problem of excellent adhesion seems to be close to a practical solution. The German light metal engine of Porsche is already using chrome-plated aluminum cylinders with excellent success. The plating process, however, is still relatively expensive. The development and introduction of such a chrome plating process on a high quality level and at economical costs would no doubt be a big impetus for all light metal engines.

The final design of a V-8 engine block in aluminum die casting may weigh between 50 and 70 lb. as noted, the die casting machine to handle blocks up to 75 lb. With all this work far advanced and the basic die cast problems solved, we believe that it will be easier for us to die cast a commercial 8-cylinder V-type block than the 6-cylinder block. Its length is appreciably shorter than the 6-cylinder block. The casting is more compact, better to fill and to eject. All heavy walls have been eliminated. Double walls connecting the crankshaft bearing with the side walls of the cylinder are making the die cast block extremely strong and well suited for an expected increase of the compression ratio.

It is, of course, only fair to mention that our work on the die cast V-8 engine block is still in the designing stage.

(Complete paper in multilith form is available from SAE Special Publications Department, 485 Lexington Ave., New York 17, N. Y. Price: 35¢ to members; 60¢ to nonmembers.)

A Manufacturing Sequence Plan . . .

. . . is a prerequisite to a coordinated tool schedule which can help to bring engineering and manufacturing closer together.

Based on secretary's report by **E. J. Hall,** Lockheed Aircraft Corp.

A COORDINATED tool schedule can help to bring Engineering and Manufacturing closer together. But a manufacturing sequence plan is a prerequisite to a coordinated tool schedule.

FIRST, management must tell Tool Control the desired completion date. THEN, engineering must give the configuration of the product. AND, Tool Planning must assist with the type and quality of tools. FINALLY, Production must help with the establishment of manufacturing flow time.

Armed with this information, Tool Control can place on a chart its manufacturing sequence plan . . . prior to the design of the article. Then, the tool schedule can be aligned to the manufacturing plan.

From the combination of manufacturing sequence and tooling sequence charts, the material procurement groups and the engineering departments can be furnished with required schedule dates to coordinate engineering materials and tooling with production.

(Complete secretary's report of panel on "Tool Control" at SAE Aeronautic Meeting and Production Forum, Oct. 11, 1955, is available in full together with 14 other panel sessions from SAE Special Publications, 485 Lexington Ave., New York 17, N. Y. Price: $2.00 to members; $4.00 to nonmembers.)

Long Range DC-8 Is OK for Shorter Ranges Too

Richard S. Shevell
Douglas Aircraft Co., Inc.

Based on paper "Versatile Jet Transport" presented at the SAE National Aeronautic Meeting, New York, April, 1956. This paper will be published in full in SAE Transactions.

THE DC-8—a large, long-range jet transport—retains its speed and cost advantages at both moderate and short ranges—if passenger traffic is high enough—thanks to such improvements as:

1. Lower fuel consumption.
2. Ability to fly more efficiently at altitudes other than the optimum.
3. Ability to fly more efficiently at nonstandard ambient temperature.
4. More satisfactory performance after engine failure.

Fuel Economy

Fuel consumption—heretofore the primary problem with jet engines—has been greatly improved in the DC-8. This lower specific fuel consumption is also better maintained at the lower speeds and altitudes at which planes hold over a weathered-in airport.

Improved fuel consumption results in more economical operation. It also helps to reduce holdover fuel requirements.

Fig. 1 shows that the DC-8 has a 38% lower sfc than a 1947 jet transport study airplane.

Fig. 2 shows that the effect of altitude on sfc is much less for the DC-8 than for the 1947 jet engine. Similarly, Fig. 3 shows that the increase in sfc of the DC-8 as the thrust is reduced is much less than for the earlier engine.

Despite these advances, the quantity of holding fuel required per hour is still large. On the DC-8 with Pratt & Whitney J-75 engines, 9000 lb per hr is needed to hold at 15,000-ft altitude. The piston-engine-powered DC-6B requires only 1420 lb per hr for holding at 10,000 ft.

Translated into reserve fuel requirements, we find that the reserve fuel is 5.7% of the maximum take-off weight for the DC-8 and 3.6% for the DC-6B. Although the jet requirement is larger, the difference is only 2% of the take-off weight. When viewed in terms of the total lifting ability of the jet transport, it is just another design requirement.

It is true, nonetheless, that extended holding requirements will have more severe effects on the jet- than on the reciprocating-engine airplane. The jet can carry sufficient reserve for all normal requirements, but improved landing aids may be needed to avoid increased diversion to alternate airports.

Effect of Varying Cruising Altitude

When the DC-8 is used for short-range operation, and fuel is not critical, it has great flexibility with regard to cruising altitude. Contrary to early concepts it does not have to dash up to 40,000 ft. It may be scheduled at any altitude between 20,000 and 40,000 ft, according to the dictates of wind, weather, and the requirements of airways traffic control without having any great effect on:

1. Block speed.
2. Direct operating costs.

Block Speed—The effect of altitude on block speed is relatively minor, as shown in Fig. 4. This graph shows the block speed effects at ranges of 200–1000 nautical miles as well as at maximum range. The curves are based on cruising at the drag divergence Mach number (the Mach number above which

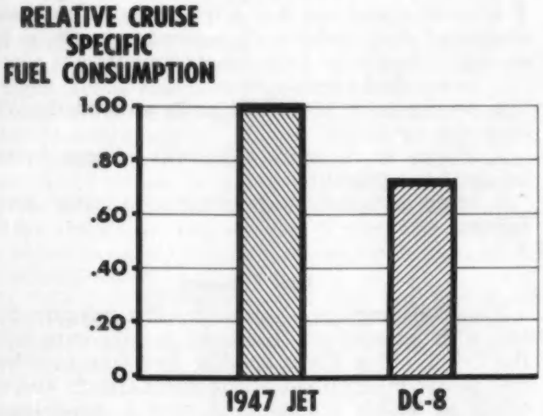


Fig. 1—Comparison of relative cruising specific fuel consumption for 1947 jet study airplane and DC-8.

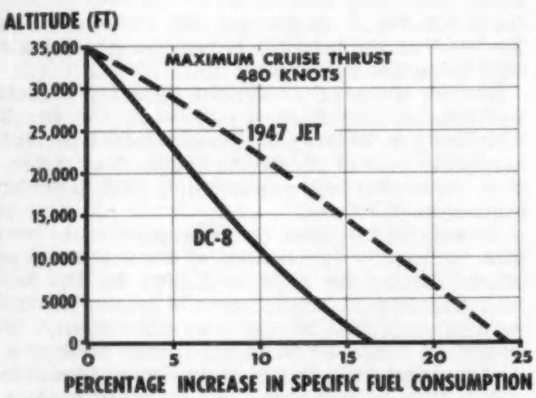


Fig. 2—Effect of altitude on specific fuel consumption for 1947 jet and DC-8.

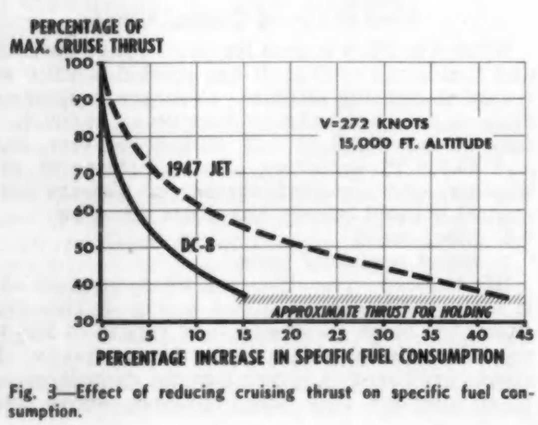


Fig. 3—Effect of reducing cruising thrust on specific fuel consumption.

wasteful increases in drag due to compressibility are incurred) except for the dashed curve, which represents long-range operation at each altitude. The block speeds are improved at the lower altitudes with high-speed operation. At altitudes below 20,000 ft the cruising speed is restricted by the structural placard speed, and the block speed is reduced. The long-range-operation curve shows the speed loss suffered if maximum range must be attained at the lower altitudes.

Direct Operating Costs—In Fig. 5 altitude is shown to have a relatively small effect on direct operating costs. These costs (calculated from the 1955 ATA cost equations) are based on a domestic first-class interior. The increased block speeds at lower altitudes tend to counteract the additional fuel cost that comes with the increased fuel consumption of lower-altitude operation. The shorter the range, the less the increase in cost resulting from reducing the cruising altitude. At 400 nautical miles range, the cost is increased only 7% by flying at 20,000 ft instead of 35,000 ft, while speeds are increased 2%. At ranges close to maximum, altitude affects operating cost to a larger extent. But even when the altitude is reduced from the optimum to 30,000 ft, the effect on cost is only 5% with high-speed operation. This assumes, of course, that full payload can be carried at all altitudes. If the payload must be reduced to fly the range at the reduced altitude, then the effects on costs are very large. An additional penalty of about 2% is incurred even if full payload is carried when long-range operation must be used at the low altitudes.

Effect of Nonstandard Ambient Temperature

The DC-8 with the J-75 engine is not thrust-limited but flies under standard temperature conditions with considerably less than the maximum cruising thrust. Therefore, although the maximum cruising thrust is reduced on a hot day, there is still sufficient thrust to fly at the same desirable Mach number up to between 20 and 30 deg about the standard atmospheric temperature. For the long-range case with variable altitude, the airplane would fly at the same

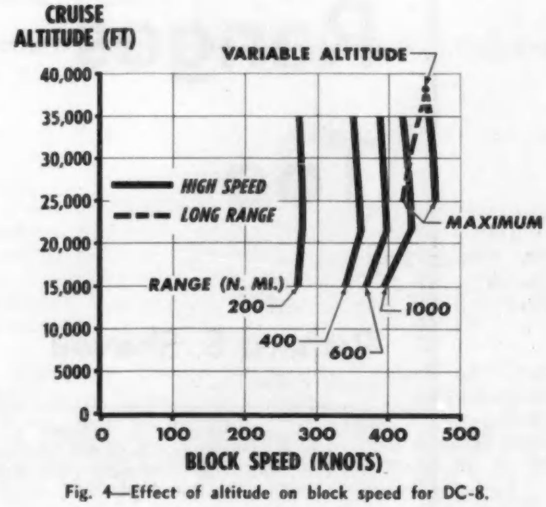


Fig. 4—Effect of altitude on block speed for DC-8.

angle of attack, Mach number, and altitude as on a standard day. The speed is increased when the airplane flies at the same Mach number with a higher air temperature. An increase in specific range—or miles per pound of fuel—might, therefore, be expected. It turns out, however, that this increase is generally canceled by an increase in sfc, so that the range is not significantly affected by ambient temperature in a non-thrust-limited airplane. The effects are the same when cruising at constant altitude on a hot day with the non-thrust-limited airplane.

If the jet is thrust-limited on a standard day, as is the Pratt & Whitney J-57-powered DC-8, there will be a hot-day speed and altitude reduction and an associated loss in specific range along the optimum long-range flight path. At constant altitude the thrust-limited airplane will usually fly at a reduced speed on a hot day and with an increased specific range. The latter occurs because, in general, the standard day cruising procedure will have been at a speed well above the best-range speed. The thrust limitation imposed by increased temperature moves the airplane flight attitude toward the long-range condition for that altitude, that is, a lower equivalent airspeed and a higher angle of attack closer to the optimum lift-drag attitude.

Fig. 6 (which illustrates only the long-range condition) shows that increased ambient temperature has a small favorable effect on the DC-8 with J-75 engines. The range with temperatures 20 deg above standard is increased ½% while the speed increases 2½%. The DC-8 with J-57 engines suffers a 4½% range loss and a 2% speed loss under these conditions. The DC-6B lies in an intermediate position, having a range loss of 1½% and a speed loss of 1%. The long-range versions of the DC-8, being equipped with J-75's, are less sensitive to temperature than reciprocating-engine aircraft.

These temperature characteristics may have an important influence on operating costs when the average cruising air temperatures are above standard. With temperatures 20 deg above standard, the

A Word of Caution

IN discussing the short-range possibilities of the long-range Douglas DC-8, the author, in his complete paper, issues the following word of caution:

"It is not intended to suggest that the DC-8 is the ideal short-range airplane. It has been designed with a gross weight and take-off ability to carry fuel for the intercontinental routes in the overwater version and transcontinental nonstop operation in the domestic version. . . .

"If we were to concentrate on a short-range airplane powered by jet engines, the operating costs could be improved even further in an airplane of the DC-8 size. A smaller jet transport designed specifically for short routes could have operating costs approaching those of the DC-8.

"The gains in operating costs accruing from designing for a particular range will tend to balance the higher costs inherent in smaller airplanes."

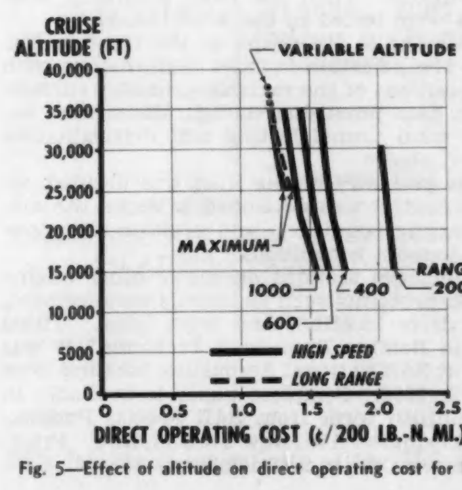


Fig. 5—Effect of altitude on direct operating cost for DC-8.

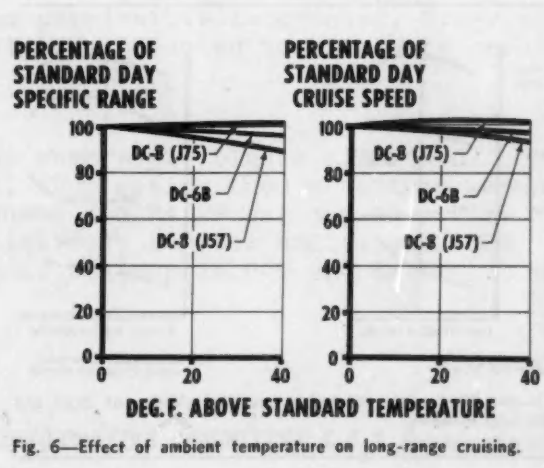


Fig. 6—Effect of ambient temperature on long-range cruising.

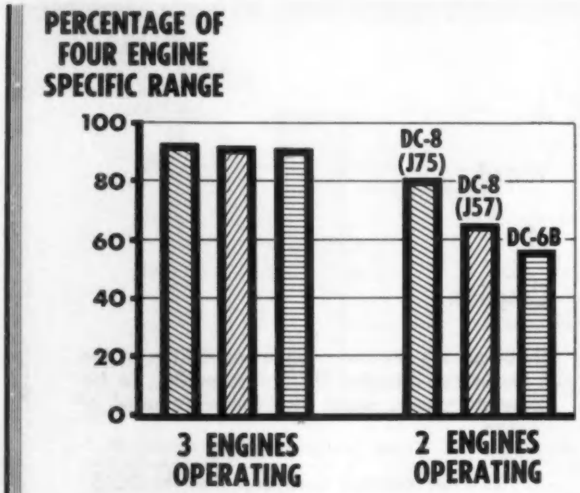


Fig. 7—Effect of partial engine operation on specific range. (For the DC-6B an average cruising weight has been used at 10,000-ft altitude for 3-engine operation and 5000-ft for 2-engine operation.)

J-75 airplane shows a speed gain of 2½%, compared to a 2% speed loss for the J-57-equipped plane. This is a relative speed gain of 4½%. The operating costs are nearly inversely proportional to cruising speed, so that the difference between the cost per mile of the J-75-powered DC-8 and the one with J-57's is substantially reduced with cruising air temperatures above standard.

Partial Engine Operation

The DC-8 is actually superior to the DC-6B at partial engine operation. Fig. 7 shows that with three engines operating, the J-75-powered DC-8, the J-57-powered DC-8, and the DC-6B show about the same specific range decrease. With two engines operating, the DC-8 with the J-75 loses only 19%, the DC-8 with the smaller J-57 loses 34%, whereas the DC-6B loses 43%. (The DC-6B shows such a large loss because 2-engine operation requires autorich powers, even at the low cruising altitude assumed.)

(For complete paper on which this abridgment is based, write SAE Special Publications Department, 485 Lexington Ave., New York 17, N. Y. Price: 35¢ to members, 60¢ to nonmembers.)

A Variable-Geometry Inlet . . .

. . . has been developed for the B-58, first U. S. supersonic bomber, to compensate for wide differences in inlet flow characteristics between subsonic and supersonic flight.

Based on paper by **Charles G. Martin, Jr.** Convair Division, General Dynamics Corp.

PRELIMINARY design studies of the main engine inlets of the Convair B-58 indicated that for overall airplane efficiency the supersonic bomber would require a multiple-shock type of inlet whose dimensions could be varied automatically to suit flight conditions.

Use of the multiple-shock inlet (instead of the conventional inlet with normal shock recovery) insures low inlet drag with high pressure recovery at supersonic speeds.

Use of a movable shape in the inlet to permit variation of its geometry makes it possible to have high overall propulsion efficiency at subsonic as well as supersonic flight speeds.

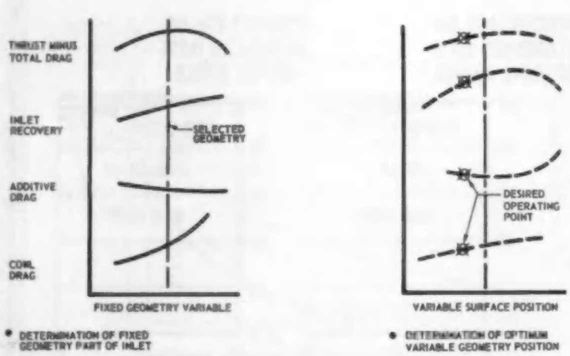


Fig. 1—Simplified version of graphs used in selection of fixed and variable inlet elements.

In designing the inlet, the fixed-geometry parts were first selected. The graph at the left in Fig. 1 gives an idea of how the thrust and drag factors varied with changes in configuration of the fixed geometry items (like lip slopes, lip thickness, and angles of the bodies producing the shock system).

Curves such as this were made for many specific flight conditions. Then the most promising configurations were tested in the wind tunnel.

Curves similar to the graph at the right in Fig. 1 indicate the variation in inlet performance with different positions of the variable-geometry surface. From such data promising configurations were selected for wind tunnel testing and determination of the final choice.

Once the geometry of the inlet was decided, an automatic control was developed to sense the airplane operating conditions and position the movable inlet element accordingly.

(Paper includes sections on many other engine installation problems such as nacelle arrangement, accessory drive location, and inlet icing. Titled "Supersonic Bomber Propulsion Problems," it was presented at SAE National Aeronautic Meeting, New York, April, 1956. Complete paper is available in full in multilith form from SAE Special Publications, 485 Lexington Ave., New York 17, N. Y. Price: 35¢ to members; 60¢ to nonmembers.)

SAE LOOKS OVERSEAS

by HUGH HARVEY, *Shell Oil Co.*

Mr. Harvey recently visited aircraft plants in England, France, and Germany and wrote this report at the invitation of the SAE Overseas Information Committee.

BRISTOL HAS NEW BRITANNIA

Bristol Aeroplane Company's latest Britannia series, 420, will use the Bristol BE 25, Orion, supercharged turboprop engine. When it is built, this airplane will have 25% more range or more payload than the 300 series planes. True airspeed will be about 415 mph. The Orion's fuel consumption is said to be 0.385 lb/ehp-hr. So far, Bristol has built only four Orion engines with about 600 hr accumulated on the test bench. Northeast Airlines has ordered 5 Britannias for delivery in October and November 1957.

ORPHEUS TURBOJET

Bristol's 4000 lb thrust turbojet, the Orpheus, weighs only 800 lb. Its weight-to-power ratio is only 0.2. It was conceived in 1954 and flew in the Folland Gnat in 1955. It is not an expendable engine and is designed to have the same life as jet fighter engines.

ROLLS-ROYCE MAINTAINS PRECISION

The Rolls-Royce plant at Derby, England, has many skilled craftsmen, yet they are not wasted on manual operations when machines can do the work. Rolls has many automatic machines, some of which are from the United States. They are apt to be torn down and rebuilt in order to decrease the permissible tolerances. Every part manufactured is carefully inspected to eliminate errors.

LOOSE COMPRESSOR BLADES

In some Rolls designs compressor blades are fixed loosely to the spool, thus giving them a certain amount of play. Both the Conway and RA 29 engines have air-cooled blades which increase turbine efficiency. The thrust of the Conway is between 14,000 and 16,000 lb at take-off.

This feature is an activity of the SAE OVERSEAS INFORMATION COMMITTEE, C. G. A. Rosen, chairman

SAE LOOKS OVERSEAS

VICKERS IS SELLING NEW VISCOUNTS

Vickers has received firm orders for 356 Viscount turboprop transports of which more than 140 have been delivered. Twenty-four of the new model 800 have been ordered by B.E.A. Aer Lingus, KLM, New Zealand National Airways, and Transair have also ordered 800's. The oval doors of the 700 series have been replaced by rectangular doors in the 800's, permitting easier freight loading. The cabin will be 9 ft 3 in. longer. Normal maximum take-off weight will be increased by 2000 lb to 62,000 lb. The engine will be the Rolls-Royce Dart 510 that is used on most Viscount 700's.

FRANCE'S OUEST BEGINS PRODUCTION OF VAUTOUR

Ouest is beginning production of the Vautour, an all-weather fighter-bomber. This airplane uses two Armstrong Siddeley Sapphire engines. The French claim it has 60% greater climbing power than the F-86 Sabre. It is designed so that by incorporating different nose sections during manufacture it can be turned out in various versions. One version, it is stated, can carry an atom bomb 1000 miles.

OUEST'S TRIDENT IS GOING INTO PRODUCTION

The 9050 Trident, probably one of the most advanced fighters in the world, is now being manufactured. It is a rectangular mid-wing, single-place fighter, powered by two French-built Babizo turbojets or two Armstrong Siddeley Viper engines on the wing tips and two or three rockets in the tail.

These rockets are powered by nitric acid and alcohol and are controllable. The French believe nitric acid is safer and more readily available than hydrogen peroxide. The Trident II can be operated from small, unpaved fields. It will probably evolve into a pilotless aircraft with armament. At present it carries air-to-air missiles under its fuselage.

LUFTHANSA REBIRTH

The rebirth of Lufthansa in Germany is nothing short of miraculous. It is due primarily to the planning that has been under way since 1948 and the cooperation of European and American airlines who placed at the new company's disposal the experience they had acquired.

EUROPE STRESSES HUMAN RESOURCES

Throughout Europe industrialists believe that well-trained technical personnel are their most important natural resource. Rolls-Royce, for example, has a very comprehensive apprentice training program which has developed workmen who take great pride in their work. Bristol has a comparable program which trains apprentices from ages 16 to 27, including university graduates. The company may also send a qualified boy to college to complete his education.

continued on page 114

Higher-octane fuels and new design get . . .

More Power from Marine Engines

R. R. Normandin, Chrysler Corp.

Based on paper "What's Happening to Modern Gasoline Marine Engines" presented at a meeting of SAE Metropolitan Section, New York, May, 1956

MORE power from any given size engine—that's what the public is demanding from today's gasoline-marine-engine builder. The engine builder, in turn, is answering these demands by building an engine which requires higher-octane fuels and which is specifically designed to obtain more power per cubic inch.

Higher-Octane Fuels

The desire for more power in marine engines has been partially satisfied by increasing compression ratios to between seven and eight to one. As a result, fuel octane requirements have increased. Formerly, volume-produced marine engines would operate satisfactorily on 60 to 65-octane fuel but today's requirements are for fuels which have a Motor octane number rating of 75 to 80, with some engines having even higher requirements.

Whether these fuels are of the leaded or nonleaded type is of little consequence provided they have the required motor octane number. Misconception, habit, or misinformation has caused a portion of the boating public to feel that a marine engine shouldn't be run on anything but marine white gasoline. This fallacy probably originated some thirty years ago when thermal cracked stock and tetraethyllead were first introduced into gasoline blends.

The early thermal cracked stocks were relatively unstable because they contained unsaturated hydrocarbons and lacked stabilizing compounds, such as oxidation inhibitors, which were not in common use at that time. When these fuels were used in boats which had large fuel tanks and were subject to long periods of storage, gum was invariably formed. This was especially true of boats equipped with copper fuel tanks which were fairly common at that time because of the material's resistance to corrosion and its ease of fabrication.

The gum formed by the reaction of the unstable fuel, oxygen from the air, and the catalytic effect of the tank material was invariably colored by the dye used to indicate the presence of tetraethyllead. Thus it appears that the boating public associated the formation of gum with the presence of tetraethyllead rather than with the actual cause, the use of unsaturated thermal cracked stocks in the gasoline blends.

Modern gasolines have undergone a gradual evolution which involved improvements in refining and

the addition of various inhibitors or additives, so that today's gasolines have sufficient stability to satisfy all normal uses. These changes in fuels, plus the gradual elimination of copper tanks, have resulted in automotive gasolines becoming entirely satisfactory for marine consumption.

The use of modern automotive fuels, with their higher anti-knock ratings, makes it possible to take more power from a given size engine by permitting greater spark advance, resulting in better operating economy and improved acceleration. The automotive type fuels also afford some degree of assurance that detonation will not occur. Detonation, when it does occur in a marine engine, is usually more injurious than in most other applications because it is encountered in the normal high speed operating range where it can be both continuous and undetected because of masking noises.

Changes in Design

A number of design changes, aimed at obtaining more power per cubic inch, are taking place in marine engines. The most common of these is the shifting of the power peak to higher operating speeds by opening up carburetors and manifolding, increasing valve size, and modifying cam contours or overlap.

All of these changes increase volumetric inefficiency at the higher speeds resulting in greater power, but at the same time they usually spoil the idle characteristics which are of foremost importance to some users.

Opening up the intake manifold has a negative effect on low speed performance because the velocities through the manifolds are not sufficiently high at low speeds to keep the fuel in suspension. The fix for this is to apply heat to the intake manifold, and the source of heat can either be jacket water or exhaust gas. Most current marine engines utilize water heat on the manifolds because it is easier to apply and control. Water heat is ideally suited for the purpose because it either remains constant at a temperature which is satisfactory for all operating conditions or it fluctuates in inverse proportion to the engine load. That is, as the load increases, the manifold temperature decreases giving the hottest manifold at an idle speed or a cooler manifold at the higher loads, exactly as desired.

When the intake manifold is the last component in the cooling system, it is always at a fairly constant temperature regardless of load, if the engine is thermostatically controlled. This temperature is usually in the range of 135 to 160 F which is warm enough to give a satisfactory idle but which is not hot enough to cause more than a 1 or 2% power loss at the higher speeds.

Putting the manifold at the start of the water circuit results in a warm manifold at idle speeds because a large portion of the water is bypassed from the thermostat back into the manifold. Then as the load is increased the temperature rise through the engine increases so that progressively less and less bypass water is recirculated through the manifold. Consequently, as the load increases the manifold temperature decreases resulting in a colder manifold at wide-open throttle, diminishing somewhat the 1 or 2% power loss encountered when the manifold temperature is held constant. The manifold temperatures, however, are slightly colder at idle if the manifold is at the beginning rather than at the end of the circuit.

(Paper on which this abridgment is based is available in full in multilith form from SAE Special Publications Department, 485 Lexington Ave., New York 17, N.Y. Price: 35¢ to members; 60¢ to nonmembers.)

Ramjet Testing . . .

. . under simulated flight conditions advanced by Air Force's new test facilities. Will also serve future turbojet engines.

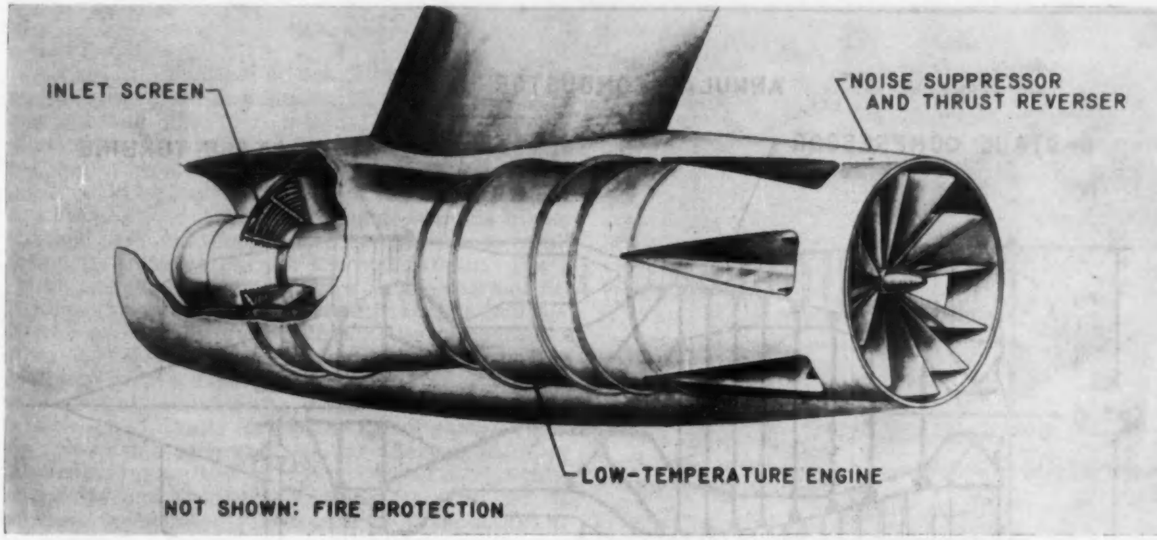
Based on paper by **Joel Ferrell and Ray W. Harvey,** Aro, Inc.

TO furnish the additional air supply and exhaust capacity needed for testing future ramjet and turbojet engines, a Ram Jet Addition (RJA) has been provided for the Engine Test Facility (ETF) at the Arnold Engineering Development Center (AEDC) at Tullahoma, Tennessee.

The RJA is composed of three air compressors, three 800 F heaters, two test chambers with individual control rooms, two exhausters, and the necessary ducting, valves and control systems for distribution to and from ETF, PWT (Propulsion Wind Tunnel) and GDF (Gas Dynamics Facility.)

The two low and one high stage compressors are started with 2500 hp synchronous motors. There are two direct-fired, continuous flow, air to air heaters and one intermittent duty heater. The two test chambers are water-cooled with overhead hatches for engine installation. J-1 test cell is 72 ft long and 16 ft in diameter with a 40-foot hatch; J-2 test cell is 63 ft long and 20 ft in diameter with a 35-foot hatch. The exhauster machines are started with a 6000 hp wound rotor induction motor and operated with a 24,500 hp synchronous motor.

ETF tests are still limited to ETF exhauster capacity but may utilize RJA airside to increase available cell pressure ratio. Combined operation for ETF-RJA will be controlled from the main control room in ETF. (Paper "Simulated Altitude Testing in the USAF Engine Test Facility" was presented at SAE National Aeronautic Meeting, Los Angeles, October 1956. It is available in full, in multilith form, from SAE Special Publications Department, 485 Lexington Ave., New York 17, N. Y. Price: 35¢ to members; 60¢ to nonmembers.)



Military Jets Need Adapting For Civilian Transport Use

Abe Silverstein and Newell D. Sanders
Lewis Flight Propulsion Laboratory, NACA

Excerpts from paper "Concepts on Turbojet Engines for Transport Application" presented at the SAE National Aeronautic Meeting, New York City, April, 1956.

FOR satisfactory transport service, the turbojet engines developed for military use will require a number of adaptations to reduce noise, increase reliability and safety. Some modifications under consideration are:

1. Lower turbine inlet temperature.
2. Noise suppressor.
3. Thrust reverser.
4. Inlet protector.
5. Crash-fire-prevention system.

Low-Temperature Engine

Lower turbine inlet temperatures will reduce the noise and improve the reliability of the engine. Before considering the possible magnitude of these gains, it is desirable to consider the effects of the reduced temperature on engine performance.

Engine Performance—Calculations show that a reduction in turbine inlet temperature from 1600 F to 1200 F results in:

1. A slight increase in fuel consumption.
2. An appreciable reduction in thrust, which may result in an increased engine size being required to produce the specified thrust.

It is possible, however, that future engines can be designed to operate at these reduced temperatures and still be no heavier than today's higher-temperature engines. These future engines would use advanced design techniques such as high airflow

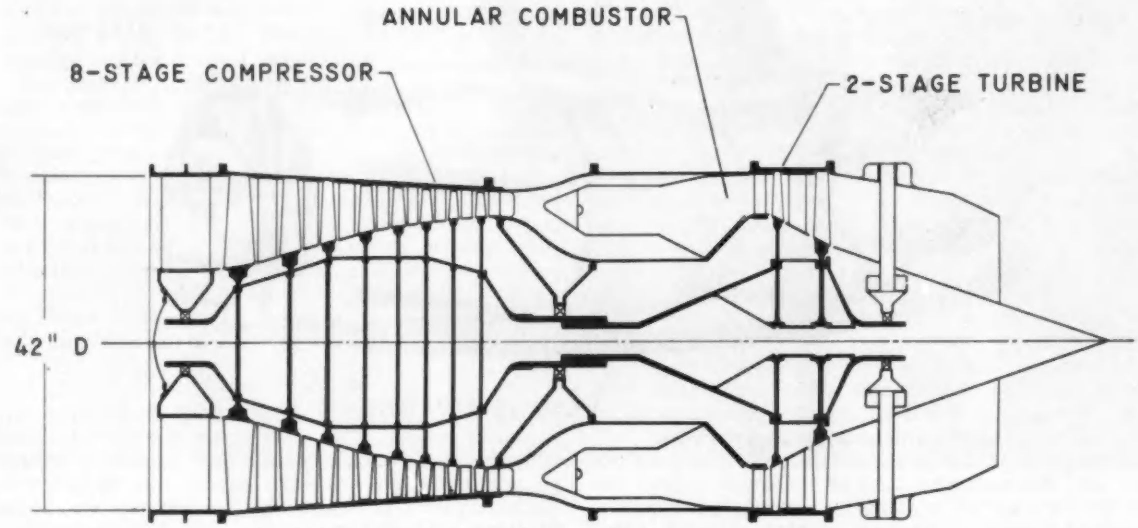


Fig. 1—Low-temperature engine having 15,000-lb thrust at sea level and 60 F.

compressors, and newer and lighter-weight materials. It would be possible, of course, to apply these advances in designs to improve the high-temperature engine. A question in the philosophy to be applied to the design of new engines is involved here. The present engines give fuel economy and weights that permit the design of economical transports. Shall we continue to apply improvements in the art of engine design to continued increase in performance, reduction in weight, and improvement in fuel economy; or shall we divert some of these gains to the achievement of other desirable operational characteristics in the engine? We believe that some of the gains to be achieved in the future should be applied to the reduction in noise and improvement in reliability of engines.

To illustrate what might be done, we have analyzed a low-temperature engine with a compressor of advanced design. The engine is illustrated in Fig. 1. The engine thrust is 15,000 lb at sea level on a 60 F day; turbine inlet temperature is 1200 F; and the compressor pressure ratio is 8. The advanced compressor pumps 20% greater airflow per unit of frontal area than do compressors in common use today. This gain of 20% largely offsets the 27% loss in air specific thrust that is incurred by going to the lower temperature. Improved stage design in combination with reduced compression ratio reduces the number of compressor stages to 8. The accompanying reduction in compressor size results in a further reduction of engine weight. Other features of the engine are a conventional annular combustor and a 2-stage turbine.

Conservative stresses have been assumed in the design. A steel compressor rotor and compressor case have been assumed. The estimated weight is approximately the same as that of present-day engines. If newer materials, such as titanium are used, the low-temperature engine would be lighter than today's engines.

From the study given here, it appears that an advanced engine having a turbine inlet temperature near 1200 F can be designed that will have a weight and size comparable to existing turbojet engines and whose fuel economy is not essentially different.

One incidental but important characteristic of the low-temperature engine is the availability of extra thrust in special circumstances such as emergencies or hot-day take-off. This extra thrust can be achieved by overspeeding the engine, thereby pumping more air and increasing turbine inlet temperature.

Noise—The principal source of noise from jet engines appears to be the jet itself. The noise is created outside of the engine by the mixing process between the high-velocity jet and the surrounding atmosphere. Experiment and theory indicate that the noise power generated varies as the eighth power of the jet velocity. Great reductions in noise can be achieved, therefore, by reducing jet velocity. Our low-temperature engine operating at 1200 F and a compressor ratio of 8 produces a jet velocity of 1557 fps as compared to 2134 fps for the high-pressure, high-temperature engine. Fig. 2 shows the relative noise levels which might be produced. The noise level is plotted as a function of the jet velocity in feet per second. The noise levels are given at 200 ft from a 4-engine jet plane producing a total thrust at take-off of 60,000 lb.

The high-pressure engine produces a noise level of 135 db and the low-temperature engine produces a noise level of 126 db—a reduction of 9 db. This is

a very welcome and worth-while reduction in noise level.

Reliability—Failures of hot parts of the turbojet engine contribute in a large measure to the lack of engine reliability. Thus, it would appear that a substantial improvement in the life and reliability of the engine would be achieved if the life of the hot parts could be improved. One of the biggest causes of difficulty, the nozzle diaphragm, is not a highly stressed part and that the damage appears to result primarily from warpage or thermal fatigue. Fig. 3 shows the effect of temperature on the thermal fatigue of two samples of high-temperature materials. In the case of inconel, reducing the temperature from 1600 F to 1200 F improves the life from 170 cycles to greater than 100,000 cycles. From this it is clear that reducing the temperature will greatly improve the thermal fatigue life of hot parts. Temperature has a somewhat similar effect upon other important properties of material. The fatigue-stress life and the stress-rupture life of materials are also tremendously improved by a reduction in temperature. Lowering the temperature will also make possible the selection of a wider class of materials for use in engine construction. At the lower temperatures higher strength materials and materials having other desirable properties become usable.

Noise Suppressor

The noise from jet engines can be reduced not only by reducing the jet velocity but also by modifying the mixing process between the jet and the surrounding atmosphere. One method for achieving the desired modification is through the selection of a proper shape of the nozzle. A large research effort is now being expended upon investigation of nozzle shapes and attachments to nozzles that will provide a noise reduction. The most promising results so far have been obtained with a type of nozzle commonly referred to as the Greatrex nozzle (Fig. 4). A nozzle of this type has been tested at the NACA. A reduction in total noise power corresponding to 6 db has been obtained with a small loss in thrust. The sound pressures in the direction of maximum noise has been reduced somewhat more—approximately 9 decibels. Other research organizations have reported even greater noise reductions. Research is continuing and perhaps still further gains will be achieved.

At the present time the performance of these nozzles have not been completely evaluated with respect to thrust loss and base drag created by these nozzles. Nor has the effect of the nozzle installation upon the drag of the complete engine installation been evaluated.

A nozzle such as shown in Fig. 4 could be applied to our low-temperature engine. The nozzle would then provide at least 6 db reduction in addition to the 9 db already accomplished. The total reduction (15 db) brings the noise level of the jet transport in line with that of large reciprocating-engine transports.

The lower-temperature exhaust gases from the low-temperature engine greatly relieves the design problem of complicated and stressed nozzles such as this noise suppressor. Particularly, the flat radial

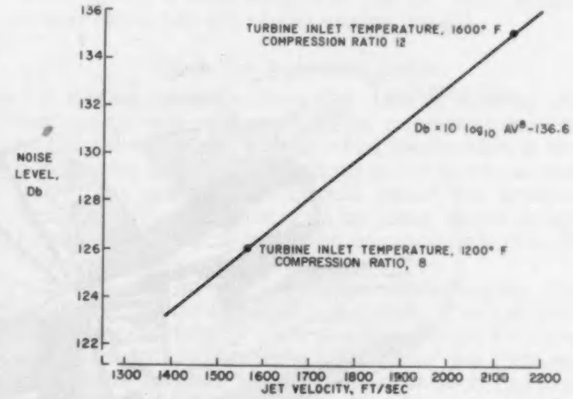


Fig. 2—Effect of jet velocity on estimated noise levels at 200 ft from 4-engine airplane at take-off.

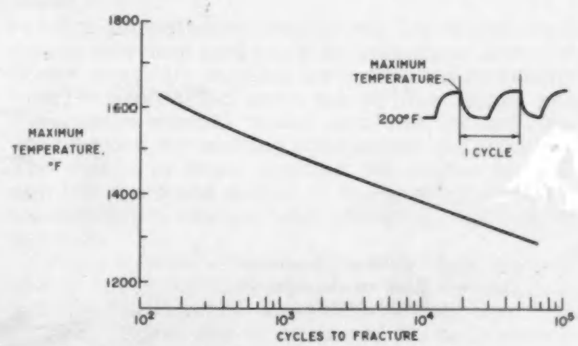


Fig. 3—Effect of temperature on thermal fatigue.

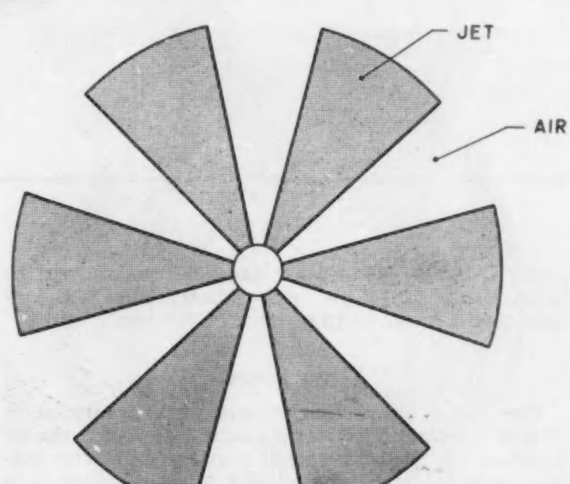


Fig. 4—Noise suppressor.

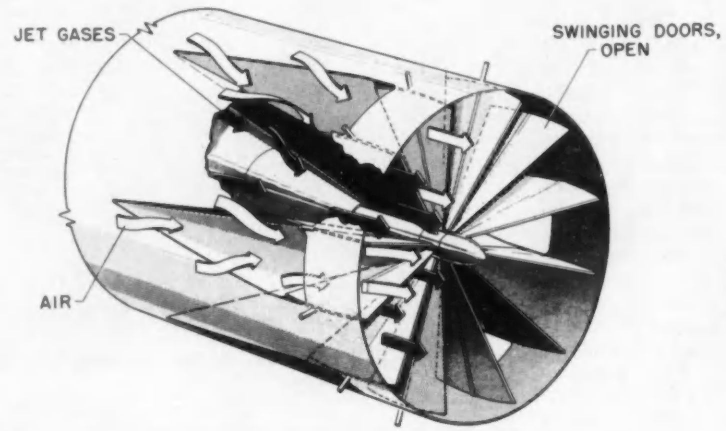


Fig. 5—Noise suppressor and thrust reverser adjusted for normal operation.

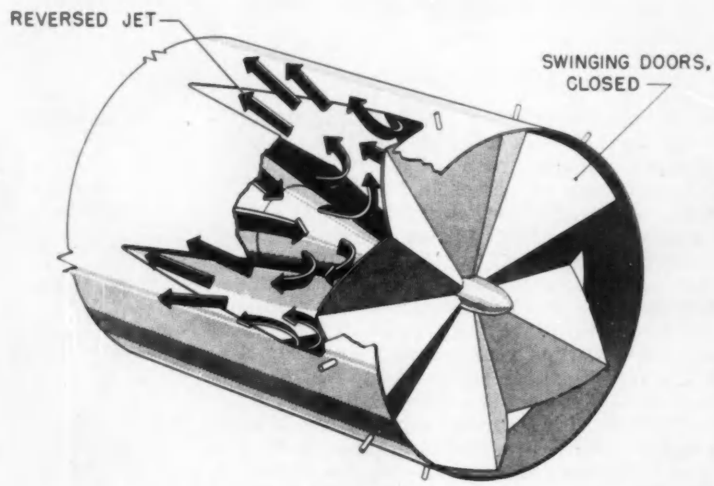


Fig. 6—Noise suppressor and thrust reverser adjusted for reverse operation.

plates between jet and air passages are subject to bending and warpage. Also, cracking at the corners might be caused by thermal stresses.

Thrust Reverser

The noise suppressor nozzle just described is readily adaptable to design modifications for thrust reversal. A thrust reverser must redirect the discharge gases from the engine so that there is a component of momentum in the forward direction. The reaction to this forward momentum appears as a reverse thrust. It is reasonable to expect a reverse thrust equal to approximately 50% of the normal engine thrust.

One suggestion for a combined noise suppressor and thrust reverser is shown in Fig. 5. Swinging doors are provided in the radial walls of the noise suppressor. These doors are normally positioned so that they are aligned with the walls and provide no obstruction to flow. When it is desired to obtain reverse thrust, these doors are swung into a position (Fig. 6) so that they block the jet passage and provide an opening into the air passage. The hot gases turn and flow backward through the air passage between the nozzle segments. The backward flow produces a component of reverse thrust. This particular arrangement of thrust reverser has not been investigated experimentally. However, experience with other types of reversal devices has indicated

that with the passage areas shown in Fig. 6 good reversal of thrust may be achieved.

The design of thrust reverser shown here is simply one idea that might be used. The design of thrust reversers seems to be mainly a matter of invention and many designs are possible. The use of a low-temperature engine again greatly improves the design problem from the standpoint of warpage of parts and reverser weight.

Inlet Protector

At the present time it appears that the most effective way to reduce foreign object damage is to place screens (Fig. 7) in the inlet to prevent objects from entering the engine. The first requirement of such a screen is its ability to remove objects of a size sufficient to cause damage. Experience has indicated that spacing successive elements or wires of the screen approximately 3/16 in. will remove the most damaging objects. The second requirement is that the screen have sufficient strength to withstand the impact of objects which enter the inlet. Very little information exists that will permit rational design from this point of view. Studies have been made with screen elements consisting of airfoil-shaped rods having a chord of 0.4 in. and a thickness of 0.094 in. These studies show that, at a Mach number in the air duct ahead of the screen of 0.3, this pressure loss is 1½% of the total pressure. Such a loss will reduce the thrust by not more than 3%.

In addition to the preceding requirements the screen must also have provisions for ice prevention or ice removal. Screens with spacing sufficiently close to provide adequate protection will ice with extreme rapidity. This icing can be of such an extent that there will be serious danger to the aircraft unless the ice is removed. One suggestion for overcoming this danger is to use retractable screens. These screens can be extended to protect the engine during the take-off run, and shortly after take-off the screens can be retracted. However, the screen must be carefully designed; otherwise, movable parts might come loose and cause damage to the engine. Furthermore, the screens must have sufficient power to permit the actuation while ice has accumulated on the screen.

A second suggestion for combating the ice problem is to provide an alternate air inlet which bypasses the screen in icing conditions. This alternate inlet can be arranged to provide a degree of inertia separation, and thereby prevent some of the foreign objects from entering. When the screen ices up the air would be forced to go through the alternate air inlet. Such an alternate inlet would probably have some pressure loss.

A third suggestion is to use electrical heat or hot gas to remove ice that might form on the screen. At the present time it appears that the electrical heating provides the most practicable method, although a hot-gas de-icing system may be possible.

The power requirement for cyclic electric de-icing is approximately 50 kw for a 15,000-lb-thrust engine. The electric power might be supplied from a 50-kw alternator driven from the engine shaft. The weight of the electrical system, including alternator leads, switches, regulator controller, timer, and other hardware, will be approximately 160 lb. In addition the screen itself weighs approximately 60 lb, giving a total weight of 220 lb. This weight is approximately 5% of the engine weight.

Crash-Fire-Prevention System

A system for preventing the start of fires by the engines in case of a crash is an important feature of the jet transport engine. Fire prevention is accomplished principally by using water sprays to cool hot metal parts of the engine below the ignition temperature of the fuel, and by using water sprays to inert combustible mixtures in spaces where such mixtures might accumulate.

In the case of the low-temperature engine, the crash-fire problem is greatly reduced. The external shell temperatures of such engines will be very low compared to temperatures of military jet engines; principally because the jet temperature is reduced to less than 765 F at take-off. The low temperature inherently improves fire safety in that the cooling time, after the power is cut off, is reduced. Also, the water requirement for bringing the temperatures of hot engine parts down to a safe temperature is lower.

A fire-protection system for the low-temperature engine described here has been tentatively designed. Water sprays are provided for cooling the combustor liner, the transition liner, the turbine casing, and the turbine wheels. Water sprays in the tail cone are provided for inerting combustible gas mixtures. The weight of water required per engine is 54 lb and the estimated weight of the entire system including water, storage tank, plumbing, and nozzles is 114 lb.

(Paper on which this abridgment is based is available in full in multilith form from SAE Special Publications Department, 485 Lexington Ave., New York 17, N.Y. Price: 35¢ to members; 60¢ to nonmembers.)

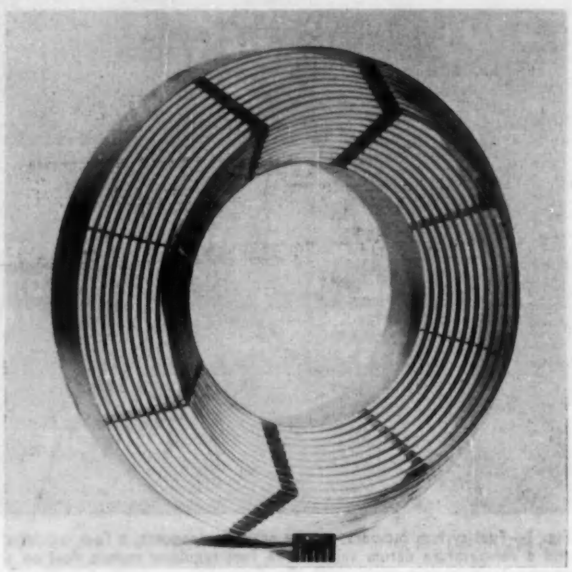


Fig. 7—Inlet screen.

Turboprop Fuel Control Can Only Limited

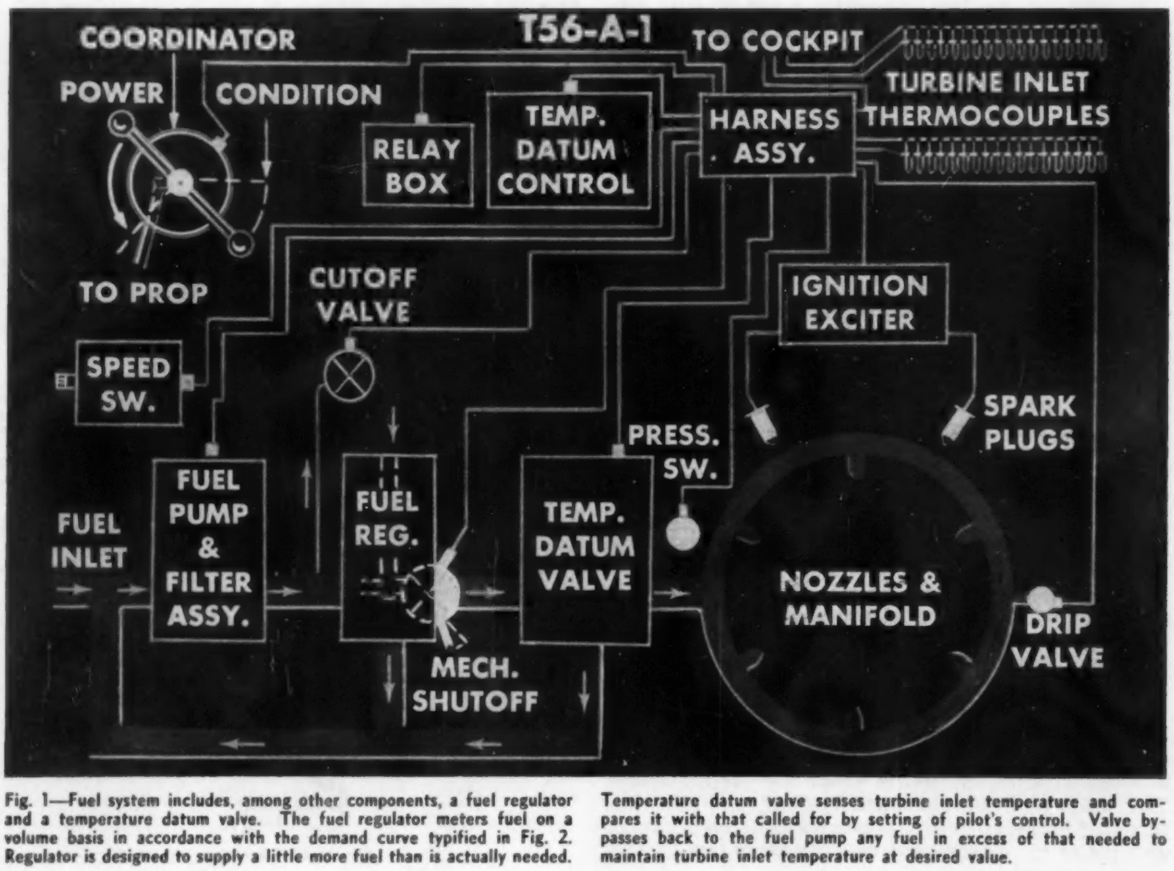


Fig. 1—Fuel system includes, among other components, a fuel regulator and a temperature datum valve. The fuel regulator meters fuel on a volume basis in accordance with the demand curve typified in Fig. 2. Regulator is designed to supply a little more fuel than is actually needed. Temperature datum valve senses turbine inlet temperature and compares it with that called for by setting of pilot's control. Valve bypasses back to the fuel pump any fuel in excess of that needed to maintain turbine inlet temperature at desired value.

F. G. Dougherty and M. C. Hardin
Allison Division, General Motors Corp.

Based on paper "General Fuel Requirements for the Commercial Aircraft Gas Turbine Engine" presented at SAE Metropolitan Section, March, 1956.

Tolerate Range of Fuel Densities

REASON why engine manufacturers consider specific gravity such an important characteristic of aircraft turbine engine fuels is that it affects the engine fuel control vitally.

Consideration of the fuel control system of the Allison 501-D13 turboprop developed for airliner application shows why:

The "fuel regulator" shown in Fig. 1 (in the lower half, just to the left of the center) regulates fuel volume flow on a predetermined schedule, like that shown in Fig. 2.

The engine requirement is for a certain fuel heat content—that is, a particular number of Btu's per unit time and therefore a particular mass flow of fuel of known heat content. But the fuel regulator works on a volume flow basis, rather than on a mass or weight flow basis. Therefore, if it meters fuels of different specific gravities at the same rate for a given condition, it delivers different weight and different heat content per unit time.

Datum Valve Allows Some Leeway

To compensate for this variation, the fuel control includes a "temperature datum valve" (in the lower center of Fig. 1). It senses turbine inlet temperature. During normal operation, the fuel regulator delivers fuel at a rate appropriate for a fuel at the light end of the specific gravity range. The datum valve bypasses back to the fuel pump any fuel in excess of that needed to maintain the turbine temperature called for by the setting of the cockpit controls.

Although the datum valve provides some latitude in fuel density (or specific gravity), there are limits to the practical range of fuel specific gravities it allows. The datum valve, of course, has to compensate also for tolerances in the engine and the control and for variations in fuel density due to the range of fuel inlet temperatures.

In view of these facts, Allison feels that a 40 to 48 API gravity range is wide, but still acceptable for satisfactory engine operation.

(Paper on which this abridgment is based is available in full in multilith form from SAE Special Publications Department, 485 Lexington Ave., New York 17, N. Y. Price: 35¢ to members, 60¢ to nonmembers.)

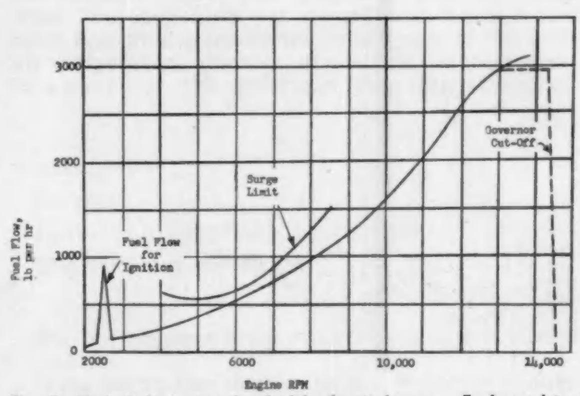


Fig. 2—Typical fuel control schedule for turboprop. Fuel regulator meters fuel to engine according to this schedule. (Momentary high flow between 2000 and 3000 rpm is to insure good spray pattern at light-off.)

The Role of the Turbine in

WHAT are the challenging problems of the gas-turbine cycle? The young engineer can easily become quite enamored over the fantastic projects which our era presents to him; however, he must not lose sight of the fact that the great automotive industry has potentials equally as significant and pertinent. The role of the turbine is most inviting. There are many goals to be reached, and a few such as the following are of significance, regardless of their application in the five categories previously mentioned.

There is the struggle for efficiency in component-design development. Textbooks on thermodynamics indicate the ideal against which all cycles are judged, namely the Carnot cycle. Here the Carnot efficiency is equal to the maximum absolute temperature of the cycle minus the absolute "sink temperature" of the cycle, divided by the maximum absolute temperature. In the Carnot cycle, part of the compression takes place under isothermal conditions and part under adiabatic conditions. Expansion also takes place initially under isothermal conditions and finally under adiabatic conditions. The constant-pressure gas-turbine cycle is called the Joule cycle. Here the air or other working fluid is first compressed adiabatically and then heated at constant pressure, after which it is re-expanded adiabatically to its original pressure. This is illustrated in Fig. 1. The Joule cycle is less efficient than the Carnot cycle because not all of the heat is added at the maximum temperature of the cycle. Also, the Joule cycle rejects a portion of the heat at a temperature higher than the minimum temperature of the cycle thus causing deviations from the Carnot cycle. The efficiency of the Joule cycle is given by the expression:

$$\eta_v = 1 - \frac{1}{r^{\frac{k-1}{k}}} \tag{1}$$

where:

r = Pressure ratio of the cycle

k = Ratio of specific heats of the working media

From this it can be seen that the efficiency of the Joule cycle for a given heat-energy input varies as a factor one minus inversely a fraction involving pressure ratio. The higher the pressure ratio (which will invariably have higher temperatures), the closer the cycle efficiency will approach one.

The overall efficiency of a simple gas-turbine unit operating on an optimum Joule cycle efficiency would be obtained with the highest possible pressure ratio. However, there are practical limits as to

C. G. A. Rosen, Caterpillar Tractor Co.

Excerpts from paper "The Role of the Turbine in Future Vehicle Powerplants" presented at SAE Chicago Section, October, 1956.

Future Vehicle Powerplants

the extent to which pressure ratio can be increased. If definite values are given for compressor efficiency, turbine efficiency, and maximum gas temperature, then a curve of overall thermal efficiency in relation to pressure ratio may be plotted from the expression:

$$\eta_0 = \frac{\eta_t \eta_c (R-1)}{\eta_c (R-1)} \times \left(1 - \frac{1}{r^{\frac{k-1}{k}}}\right) \tag{2}$$

This is only a close approximation, but represents a useful expression to evaluate trends as shown in Fig. 2 (from footnote 1). In this expression η_0 is the overall efficiency. η_t is the turbine efficiency and η_c the compressor efficiency. R represents the ratio of positive to negative work in the ideal cycle or the ratio of T_{max} to the ideal adiabatic compression temperature. The expression neglects a number of factors such as, the effect of variable specific heat, the losses in ducting, the additional work derived from the mass flow of the fuel passing through the turbine in the form of combustion products, and the proportion of useful work ultimately regained in the turbine from the extra heat derived from inefficient compression. The expression is based on the assumption of an ideal or reversible Joule cycle. When considering an actual process the picture changes considerably.

The thermal efficiency of the real cycle may be stated as:

$$\eta_0 = \frac{W_t - W_c}{Q}$$

where:

W_t = Work done by the turbine, Btu per lb

W_c = Work input to compressor, Btu per lb

Q = Heat transfer to system, Btu per lb

By substituting values in terms of temperatures, efficiencies and pressure ratio, the equation becomes, for reference cycle notations, Fig. 1.

$$\eta_0 = \frac{\left(r^{\frac{k-1}{k}} - 1\right)\left[\frac{T_c \eta_t}{r^{\frac{k-1}{k}}} - \frac{T_A}{\eta_c}\right]\eta_f}{T_c - T_A\left(1 + \frac{r^{\frac{k-1}{k}} - 1}{\eta_c}\right)}$$

By assuming various values, such as T_{max} equal to 1300 F, an ambient equal to 60 F, η_t equal to 88% and η_c equal to 84%, and η_f equal to a combustion efficiency of 95%, the intermediate curve in Fig. 2 is obtained. Here also it can be seen that for any given T_{max} there is a point beyond which no gain is obtained in efficiency at higher pressure ratios. The curves also indicate the relationship of overall efficiencies to T_{max}.

Influence of Component Efficiencies

The gain in maximum specific power, in horsepower per pound of mass flow per second, is almost twice as much for 1500 deg T_{max} as it is for 1100 deg T_{max}. This is of interest in evaluating the influence of component efficiency on power versus pressure ratio as in Fig. 3 (from footnote 2). Here an increase of overall efficiency of 27½% at 5/1 pressure ratio is responsible for an increase of almost 100% in bhp output. This curve illustrates the paramount importance of the efficiencies of the two components —the compressor and the turbine. The actual design of the compressor, whether it be radial flow or axial flow, is far too complicated a matter to be considered in a paper of this character. Its design is based partly on pure theory and partly on semiempirical rules and is determined from the observed results of numerous laboratory tests in wind tunnels.

The character of a compressor may well be judged by a map as shown in Fig. 4 (from footnote 3). This performance chart is for a single-stage radial compressor with backward curved blading in a fully shrouded impeller. These curves are plotted on the basis of the so-called dimensionless equivalents of pressure, mass flow, and speed. The vertical axis is the pressure ratio. The horizontal axis represents mass flow in pounds per second and is the factor mass flow multiplied by the square root of the inlet air temperature absolute, divided by the inlet pressure absolute. The speed curves are represented as:

$$\frac{N}{\sqrt{\theta}} \tag{3}$$

where:

N = rpm

θ = Inlet air temperature (absolute)

The efficiency curves are:

$$\eta_{1ad} \tag{4}$$

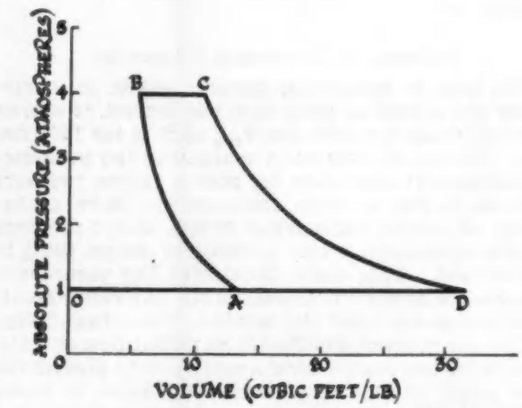
The limiting line to the left of the family of curves

[1] "The Gas Turbine Manual," by R. J. Welsh and Godfrey Waller. Pub. by Temple Press, London, 1951 and 1955.

[2] "Turbines for Vehicles," by A. A. Kucher. Presented at the National Petroleum Association, Atlantic City, September, 1955.

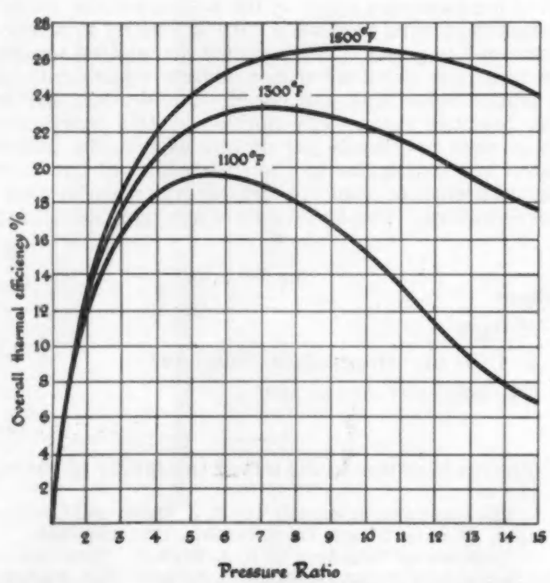
[3] SAE *Quarterly* Transactions, Vol. 6, October, 1952, pp. 753–782: "Superchargers and Their Comparative Performance," by W. T. von der Nuell.

is called the surge line beyond which the compressor will not operate properly. It is usually necessary that the aerodynamic and mechanical features of a prototype compressor be modified considerably as a result of direct full-scale tests on the actual machine itself. For this reason, the compressor in the gas-turbine assembly represents the costliest component to develop. Despite its complexity some rather astounding results have recently been achieved as reported by Boeing.[4] In a single-stage radial compressor, pressure ratios as high as 7/1 were achieved experimentally. Of particular interest in this development is the vortex diffusor, a device in which the velocity energy of the air leaving the impeller is converted to pressure energy in a nozzle-like arrangement working in reverse. In the case of a centrifugal compressor the function of the diffusor is very vital, since more than 50% of the comparison is done in the impeller, the remainder being performed in a diffusor system. In the Boeing vortex diffusor, supersonic velocities represented by Mach number 1.3 leave the impeller and are transformed in the diffusor to Mach numbers of 0.2. These tests indicate some stimulating possibilities in designing single-stage compressors of pressure ratios as high as 10/1, with tip speeds between 1800 and 2000 fps and adiabatic efficiencies in the range of 75 to 85%.



Courtesy, "The Gas Turbine Manual"

Fig. 1—Simple gas turbine *PV* diagram.



Courtesy, "The Gas Turbine Manual"

Fig. 2—Overall thermal efficiency versus pressure ratio.

The component efficiency of the turbine is playing a leading role in the task of gas-turbine design. It carries the most highly stressed elements due to effects of high temperature and high-rotative speeds. Its temperature limitations are usually the criteria which determine the maximum gas temperature of the cycle and, therefore, its efficiency as a component is of great importance. The turbine can be either of the axial-flow type with alternate rows of fixed and movable blades for multistages, or in the case of smaller units of the centripetal type designed as a radial-inward-flow turbine.

High-Temperature Materials

Because of the limitation placed by the hot wheel or turbine wheel on the maximum temperature to which the unit can be subjected, the material entering its construction is of major significance. The material must carry high stresses continuously at high temperature and without creep. Provision must be made to permit thermal expansion to take place freely in every direction. All parts operating at high temperature should be made as small as possible to reduce internal thermal stresses. Wherever pos-

[4] "Development of Centrifugal Compressor for Small Gas-Turbine Engine," by N. R. Balling and V. W. Van Ornum. Presented at ASME Gas Turbine Power Conference, Washington, April, 1956.

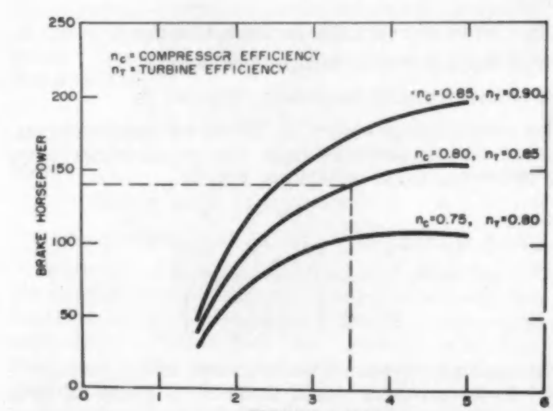


Fig. 3—Power versus pressure ratio influence of component efficiency.

sible, stressed parts should be cooled or protected from the highest gas temperatures, and the highest gas temperatures should occur under maximum stress condition only at full load. It is necessary to consider not only the stress which the material can carry but the length of time over which it can safely carry it or the "time stress" to "fatigue fracture." The influence of time on creep strain is clearly revealed in Fig. 5 (redrawn from Fig. 10 of footnote 1). The nature of these typical creep curves of high-temperature alloys with time show that the creep strain has a primary period, a secondary creep period, and a rapidly rising creep strain leading to fracture as a tertiary creep. The problem of choosing materials which are relatively insensitive to thermal shock grows more critical as the operating temperature range is widened.

In a gas turbine, the gross power output, that is, the power produced by the turbine wheel itself, will be proportional to the weight of air used per unit time multiplied by the temperature drop. Fig. 6 (from "Some Elements of Gas-Turbine Performance," by S. D. Heron, SAE Meeting, March, 1956) indicates a major reason for the present limitations upon the operating temperatures of gas turbines. It also reveals the wide differences in the stress-carrying capacity of various materials in relation to the temperature prevailing over a 1000-hr period.

To those interested in pursuing the theories supporting the fluid mechanics of turbomachinery, one is directed to the outstanding text on this subject by George F. Wislicenus. The present state of theories does not permit the exact determination of configurations such as entrance shapes of inducers or diffusor contours, but by the additional application of geometric similitude based on experimental evidence, a more direct route to development satisfaction is achieved.

The full utilization of higher T_{max} temperatures in gas turbines requires the development of new high-temperature, high-strength alloys, low in creep fatigue and resistant to thermal shock at both high and low temperatures. The combination of all these virtues usually results in excessively high-cost critical materials. To compete with the piston engine, materials as well as manufacturing cost of the gas turbine present difficult hurdles to mount. Some of the present aircraft alloys known as austenitic high-temperature-forging and -casting alloys cost as much as $4 per lb. For automotive practices the maximum allowable cost should be below $1 per lb as applied to the most expensive material entering its manufacture. Achievements in this direction have been approached by several automotive manufacturers.[5] These may very well point to the day when the expected goal of a complete automotive gas turbine will cost less than present-day piston engines in high production.

Manufacturing Costs

Fabrication facilities have been intensely developed and bid fair to permit high-volume production in the not-too-distant future. Just two years ago the forging of a specific hot turbine wheel for an automotive unit cost almost $200 after inspection and testing. Today, a comparable wheel can be finished, produced in quantity by high-precision-casting and -welding methods, for approximately $20 per unit, based on carefully predicted cost analyses.

The rather extravagant prices quoted on some available small experimental gas-turbine units are by no means a criterion of future production costs. The inclusions of tremendously costly development charges (which appear always to be associated with gas-turbine development) plus the high present alloy-material and -fabrication costs, are responsible for a distorted economic picture and are far from representative of the low-cost possibilities of the future small gas turbine.

A great challenge is placed before the young engineer for pursuing metallurgical developments in suitable materials of lower cost and of devising fabrication facilities to realize the manufacturing possibilities of an essentially extremely simple power-producing mechanism.

In larger gas turbines, blade cooling is an inviting avenue for approaching higher flame temperatures using reasonably economic alloys. The conclusions of Rohsenow[6] are, "that blade cooling will increase

The paper from which these excerpts were taken was presented as a Buckendale Lecture.

The prime purpose of the Buckendale Lectures is to direct attention toward filling the needs of young engineers and students for up-to-date practical knowledge. L. Ray Buckendale was a strong advocate of the development of the latent abilities in young men and constantly stimulated them to high goals of attainment.

The young engineer graduating from college is faced with a difficult problem of choosing a branch of engineering which he hopes to build into the structure of his career. Today he is challenged in his choice between ventures which border on the fantastic and those which have roots in a long chain of evolutionary development. The one philosophy endeavors to reduce the fantastic to the realistic—the other, to extrapolate the factual to the horizon of the imaginative. The creative urges in both categories have the same basic stimulation of seeking answers to unknowns, but the foundation stones are of different composition.

Projects on guided missiles, space locomotion, and atomic propulsion intrigue the mind beyond conventional scientific concepts. It pinpoints faith on the ultimate consummation of anticipated "breakthroughs." The resultant achievement in practical mechanisms, however, must be built on the firmer base of developed fundamentals. Upon this thesis C. G. A. Rosen has chosen his subject: "The Role of the Turbine in Future Vehicle Powerplants."

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[5] SAE Transactions, Vol. 64, 1956, pp. 582–588: "New Alloys for Automotive Turbines," by Donald N. Frey.

[6] "Effect of Turbine Blade Cooling and Efficiency of a Simple Gas-Turbine Powerplant," by W. N. Rohsenow. Presented at ASME Diamond Jubilee Annual Meeting, Chicago, November, 1955.

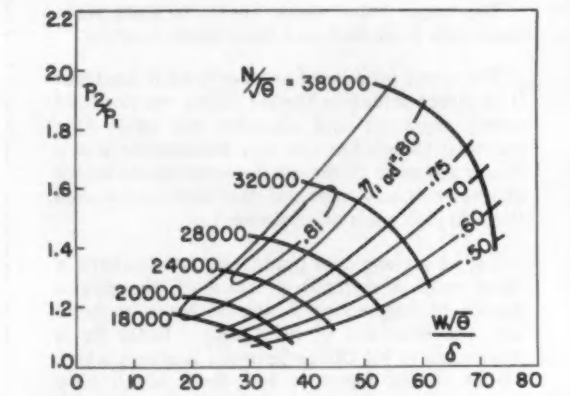
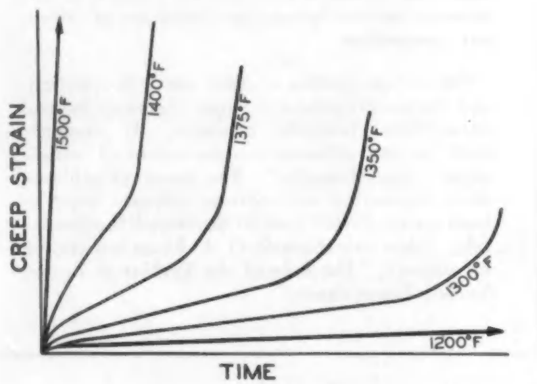


Fig. 4—Performance chart of single-stage radial compressor with backward curve blading in fully shrouded impeller.



Courtesy, "The Gas Turbine Manual"

Fig. 5—Typical creep curves at various temperatures.

the efficiency of the gas turbine considerably—the increase in flame temperature will cause an increase in pressure ratio in order to obtain maximum efficiency. . . . The turbine requiring cooling to 1000 F obtains efficiencies which are within 2 or 3% of those obtained by the turbine using more expensive materials when the two performances are compared at similar inlet temperatures and pressure ratios." Gas temperatures in the range of 1000 F permit the use of lower cost materials which are in the category of those used in conventional steam-turbine practice.

Gas-Turbine Fuels and Lubricants

The gas turbine is truly a multifuel engine since it is capable of operating on a wide range and variety of liquid hydrocarbon fuels. Notwithstanding its broad appetite in consuming distillate fuels of wide boiling range from gasoline to the heavy diesel fuels, it is not particularly digestive of leaded gasolines. Leaded gasolines in general reduce service life of the powerplant. The acceptable wide boiling range permits the utilization of fuels which require less processing of a barrel of crude oil and therefore permits greater yield in products suitable for gas turbines. The optimum fuel characteristics have not as yet been determined. It is known, for instance, that the high temperatures in the combustor release corrosive products in the form of materials containing sulphur, sodium, and vanadium.

In locomotive gas-turbine service, fuel deposits have been alleviated by using additional metallic additives such as magnesium. These prevent the deposition of nonvolatile products of combustion on critical blade surfaces and control contours. These are, nevertheless, factors which will restrict the use of the lower cost residual fuels in automotive-type gas turbines until the character of the deposits and their formation are more clearly understood. In general, it can be said that carbon formation can be controlled by the burner and its combustor design, whereas the accumulation of carbon and other nonvolatile fuel components in the intricate passages of the regenerator can cause a serious operating problem. Such deposits would reduce heat-transfer rates and increase pressure drops across the regenerator.

The broadest experience in the utilization of wide-range fuels has been obtained by the Union Pacific Railroad on its gas-turbine locomotives. The short supply of residual acceptable liquid fuels has indicated the desirability of ultimately utilizing coal as fuel for locomotives. The problems in burning coal are being thoroughly investigated, but the chances are that coal or solid fuels of any kind will never become very significant in automotive gas-turbine equipment.

While discussing petroleum products, the lubricants necessary for proper lubrication of high-speed bearings is a more difficult one than is usually found in automotive-type piston engines. The severest condition imposed upon a gas-turbine lubricant is that of repeated accelerations and decelerations which impose high "soak-back temperatures" into the shaft and the bearings. Also, a quick stall of the gas turbine is a factor in the rapid temperature buildup of the oil film. Synthetic lubricants have been used in aircraft and are experimentally satisfactory in gas turbines; however, the field-service problems involving "soak-back temperatures" of 600 F could be deleterious to synthetic lubricants. Much work is yet needed to be done on bearing lubrication.

Combustion Studies

It is of interest to study the influence of fuels and fuel systems in relation to combustion efficiency, while attempting to extend the limits of combustion intensity. Some very pertinent thoughts on this subject have already been presented by J. J. Broeze.[7] In Fig. 7 (from footnote 7) the heat-release rate in relation to density is plotted in areas of practical achievements in combustion intensity.

The horizontal axis plotted as density indicates the value of high compression ratios for combustion efficiency. The vertical axis represents the heat release in terms of kilocalories per cubic meter per

[7] Proceedings of the Fifth AGARD General Assembly, Ottawa, June, 1955, pp. 92–101: "What are the Limits of Combustion Intensity," by J. J. Broeze.

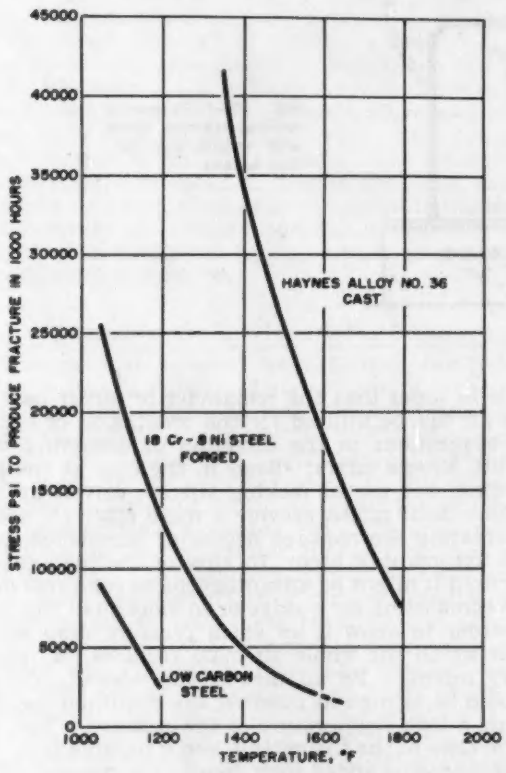


Fig. 6—Hot strength of turbine materials.

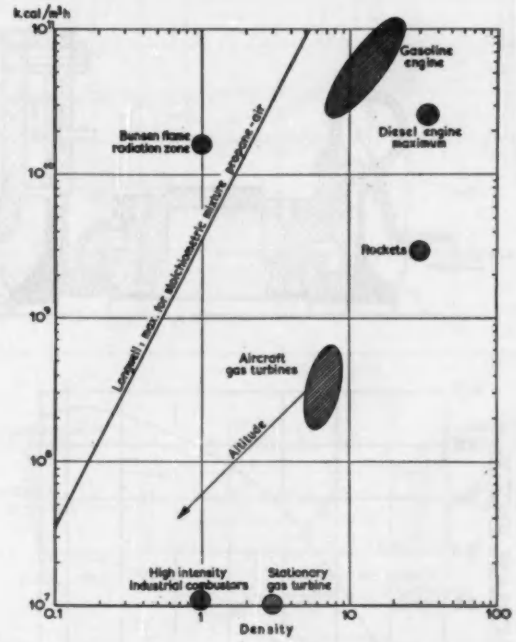


Fig. 7—Heat-release rate in areas of practical achievement in combustion intensity.

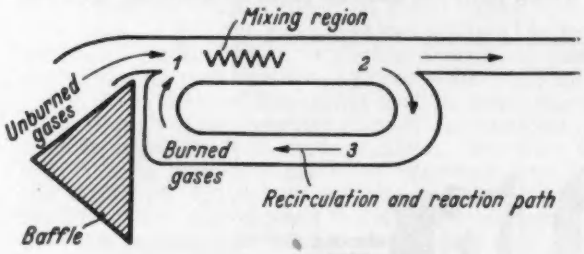
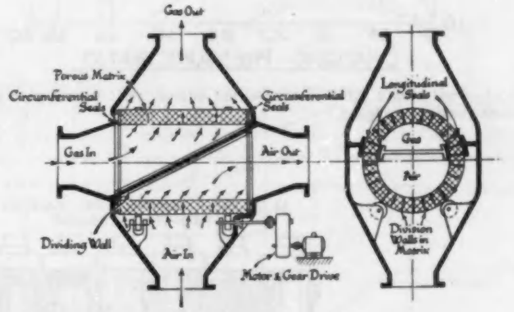


Fig. 8—Combustor flow diagram.



Courtesy, "The Gas Turbine Manual"

Fig. 9—Rotary type of regenerator.

hour. This indicates also the relative areas and positions occupied by the gasoline engine, the diesel engine, and the gas turbine. All of them, however, are still remote from the limit line established by Longwell. This should stimulate continued research in the direction of achieving higher combustion intensity. It is also to be noted that fuels are a factor in the picture and that our knowledge is not complete with respect to what can be accomplished by new developments in fuels to improve the intensity of heat release.

According to Broeze: "For stoichiometric mixtures the attainment of still higher rates, up to the limiting line is mainly a matter of providing adequate turbulence; adequate in degree in order to utilize to the full the spreading power inherent in the incoming gas velocity, adequate in fineness of structure in order to minimize the distance of travel of particles."

To achieve high-combustion intensity in gas turbines, the compressed charge for primary combustion must be brought as near to stagnation as pos-

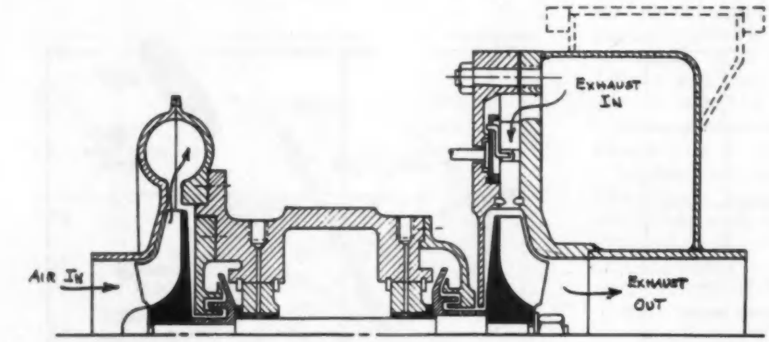


Fig. 10—AiResearch turbosupercharger fitted with variable-area turbine nozzles.

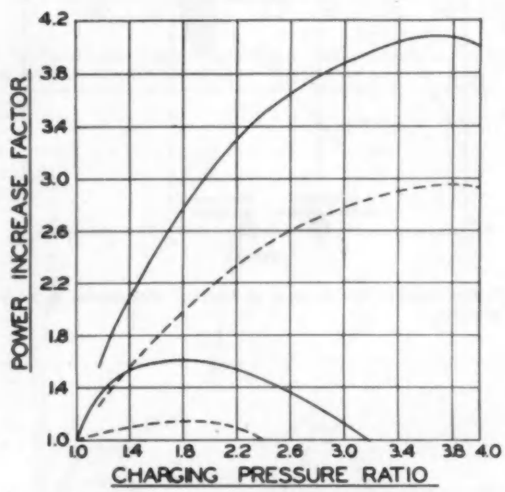


Fig. 11—Four-stroke internal-combustion-engine performance plot with exhaust turbine charging.

sible in order that the remainder or larger part of the air can be utilized for the production of eddys. As suggestions in the direction of achieving this result, Broeze offers: "Even in the case of the gas turbine, the use of moving stirrers driven by the engine itself might provide a more efficient means of creating the required degree of turbulence than the fixtures now used. In view of the high-excess air used it might be advantageous to compress only the combustion air a stage or so more than the rest, in order to allow it an extra pressure drop above that which the whole air mass requires for secondary mixing. By all means, the normal mixture should be as high as possible, the condition for this being a high temperature of the mixture, a fuel/air ratio close to the theoretical, and a suitable fuel. To this should be added high density for completion of combustion in short periods."

Further studies are needed to emphasize the physical processes of mixing fuel and oxygen and burned and unburned gases and the chemical processes which limit the possible rates of reaction. The lim-

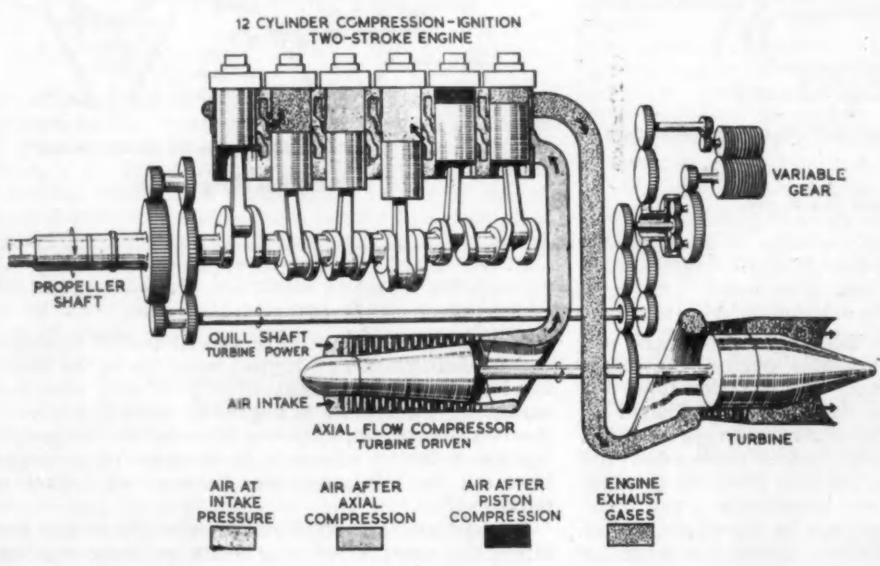


Fig. 12—Napier Nomad compound engine.

its of intensity of combustion are also curbed by flame stability. Stability and intensity are to some extent incompatible. Fig. 8 (from footnote 8) shows, diagrammatically, the problem as presented by Spalding.[8] The rate of supply of reactants to the combustion chamber should be sufficiently great so that the flame is not quite extinguished under the most adverse conditions of temperature and pressure. The designer of a gas turbine must compromise between a number of factors. The combustion system should be small in volume and light, should produce a stream of hot gases of substantial uniform temperature and velocity, and should have the minimum of consumption of fuel and a maximum of mechanical endurance.

Regenerators for Part-Throttle Fuel Economy

The gas turbine must compete with the piston-type engine, not only of today, but of tomorrow. With rising compression ratios in automotive-type gasoline engines, there will be stiffer competition for the gas turbine to achieve reasonably comparable part-throttle fuel economy. In this competition the regenerator definitely enters the picture as has been previously pointed out. The problems introduced by the regenerator, however, are not simple to solve. The stationary type of heat exchanger with sufficient heat-transfer surfaces should prove effective, say for 75% heat recovery, but assumes bulky volumes difficult to install in some automotive equipment. The rotary regenerator type has its appeal with regard to dimensional limits which are acceptable. In the Plymouth installation of the Chrysler gas turbine, the competitive gas-turbine unit with its heat regenerator is installed within the same hood limits as the present piston engine. The rotary type of regenerator as shown schematically in Fig. 9 (from footnote 1) is besieged with the problem of maintaining suitable seals, permitting a matrix to pass from a zone of hot-gas stream into a cold airstream without too great a seal loss or pressure drop. A relatively low seal loss renders the regenerator ineffective in achieving acceptable fuel economies at part throttle. These seals must accommodate thermal expansion and in some cases must slide over an irregular surface operating at a high temperature without lubrication. To effect a reduction in hydraulic diameter, problems arise in the design of the regenerator matrix. The manufacture of the matrix itself is difficult so as to provide the compact surface structure consisting of a large number of very narrow flow paths yielding a large heat-transfer surface per unit volume, but sufficiently free to prevent plugging by deposits. Many of these problems have been solved in the laboratory, but the effectiveness of the regenerator under field-operating conditions still presents problems which command the attention of engineers.

High-Pressure-Ratio Supercharging

Under the heading of high-pressure-ratio supercharging only the turbine-driven type of compressor of Fig. 10 (from footnote 3), in one or more stages will be considered. The exhaust turbosupercharger

[8] "Some Fundamentals of Combustion," by D. B. Spalding. Pub. by Academic Press, Inc., New York, 1955.

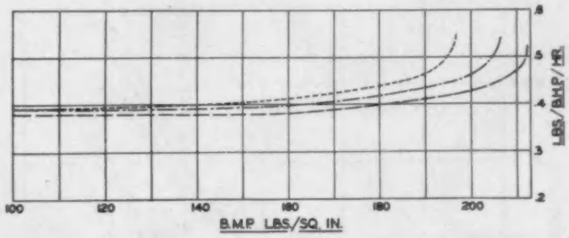


Fig. 13—Fuel consumption curves on heavy residual-type fuels using Ricardo Comet System's turbosupercharger.

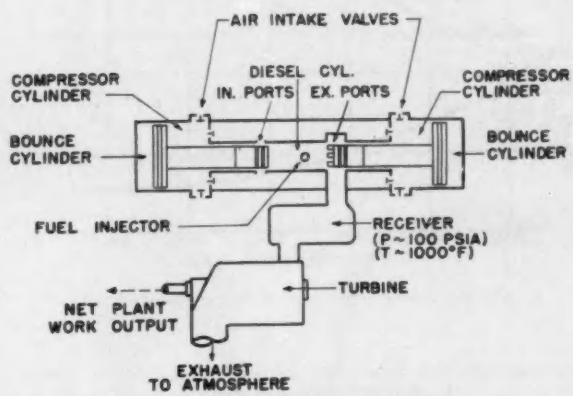


Fig. 14—Free-piston compound powerplant.

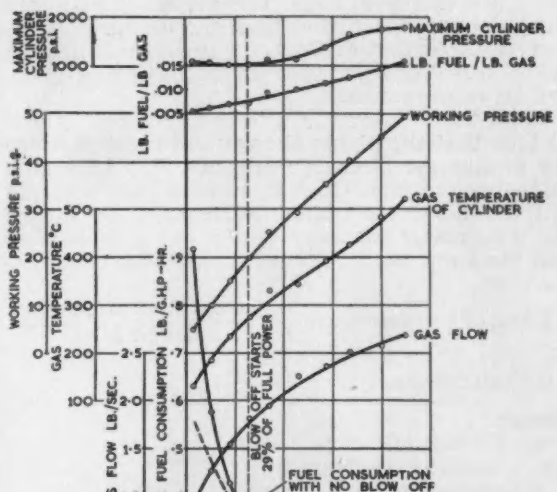


Fig. 15—Performance curves of free-piston gasifier.

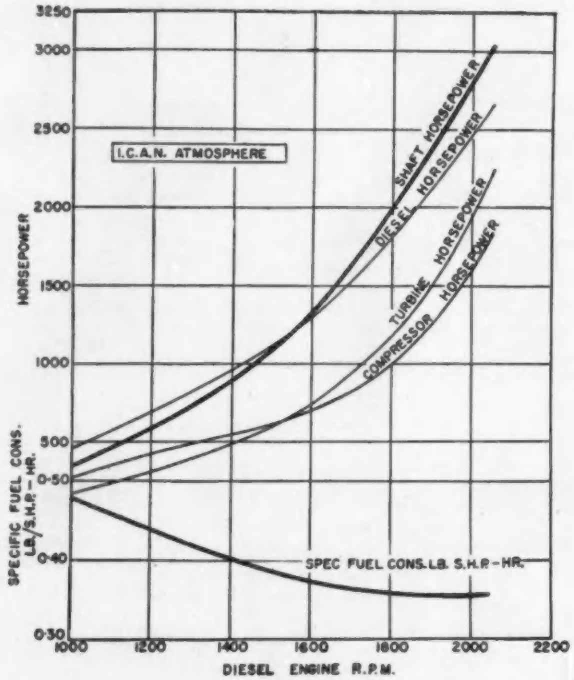


Fig. 16—Performance curves of Napier Nomad engine.

represents the most economical drive for a supercharger in that a turbine exacting energy from the engine's exhaust gas is utilized to drive the compressor. To utilize to best advantage the available enthalpy drop, the gas pressure must be higher at the turbine inlet than at its outlet. In general, when using a turbosupercharger one desires to maintain the boost pressure higher than the discharge pressure of the cylinder. By boost pressure is defined the manifold pressure charged to the engine cylinder above atmospheric.

From the following generalized equation[3] it can be seen that the higher the ratio of boost pressure (or compressor discharge pressure, P_{c2}) to engine discharge pressure, (that is, turbine inlet pressure P_{t1}) the higher the turbine efficiency η_t, the higher the compressor efficiency η_c and gas temperature, and the lower the air temperature at the compressor inlet.

Ratio of boost pressure $\frac{P_{c2}}{P_{t1}} \; \frac{\text{compressor discharge}}{\text{turbine inlet}}$

Overall efficiency $\eta_o = \eta_t \times \eta_c = \frac{1}{r} \cdot \frac{H_c}{H_t}$

where:

η_t = Turbine efficiency
η_c = Compressor efficiency
r = Pressure ratio
H_c = Adiabatic head compressor
H_t = Adiabatic head turbine

Introducing pressures and temperatures and simplifying terms,

$$\eta_t \times \eta_c \times \frac{T_{\text{gas}}}{T_{\text{air}}} = \frac{1}{r} \times \frac{K_x\left[\left(\frac{P_{c2}}{P_{c1}}\right)^a - 1\right]}{K_y\left[1 - \left(\frac{P_{t2}}{P_{t1}}\right)^b\right]}$$

$\eta_t \times \eta_c \times \frac{T_{\text{gas}}}{T_{\text{air}}}$ is called characteristic τ value

and:

P_{c2} = Pressure compressor outlet
P_{c1} = Pressure compressor inlet
P_{t2} = Pressure turbine outlet
P_{t1} = Pressure turbine inlet

For simplification use:

K_x = A factor
K_y = A factor

Today, it is a well established fact that the diesel fitted with an exhaust turbosupercharger is the most economical type of thermal prime mover designed to achieve this goal. Even greater economy, however, can be obtained with increased boost pressure, augmented with additional cooling of the charging air and with improved scavenging effects in the power cylinder of the engine. These influences are readily appreciated and pose a challenge when referring to Fig. 11 (from footnote 9) as developed by Alfred J. Buchi,[9] the inventor of the exhaust turbocharger for diesel engines. In this figure the lower dotted line represents the influence of power increase in relation to the charging pressure ratio without improved scavenging or without intercoolers. Curve C shows that only a 17% boost in power is obtained at 1.8 pressure ratio under these conditions. If, however, the air discharged from the compressor is cooled to values which are represented by 75% of the temperature increase during compression, it is possible to achieve 90% power increase at the same pressure ratio. Again, by improving the scavenging of the cylinder, but without intercooling, a 60% increase is obtained at a 1.8 pressure ratio. There is further improvement to 170% of full-load power with 75% cooling of the air charge in relation to the temperature increase in the air compressor and effective scavenging. These curves are startling examples of the advantageous influence of low-charging temperature of air and satisfactory scavenging of the engine cylinders at fixed-charging pressure ratios. This represents a real challenge toward seeking their achievement in automotive practice.

A second method for increasing diesel-engine output is the application of the exhaust turbine for the combined generation of power as well as supercharging. This method differs from pure turbosupercharging in that both the internal-combustion engine and the exhaust gas turbine are arranged independently to provide power, or the separate outputs of both are transmitted through gearing to a common shaft such as in the Napier compound engine using a 2-stroke loop-scavenged power cylinder, as shown in Fig. 12 (from footnote 10). Judging by Fig. 11, based on a 4-stroke engine, the charging boost at 3.6 pressure ratio could be responsible for a power increase of as much as 307% when provided with adequate intercooling and proper scavenging. The prime deterrent in achieving these values in

[9] *Journal of the Franklin Institute*, Monograph No .1, 1953, pp. 1–75: "Exhaust Turbocharging of Internal-Combustion Engines," by Alfred J. Buchi.

[10] "Gas Turbine Principles and Practice," by Sir Harold Roxbee Cox. Pub. by Newnes, London, 1955.

practice is adequate materials. The metallurgist has an open sesame in unlimited opportunities.

The effect of overall efficiency of the exhaust turbosupercharger itself is significant in relation to its influence on the possible increase in engine-shaft output. An increase of 20% in overall adiabatic efficiency of a turbocharger at 1.8 pressure ratio without charge cooling but with suitable scavenging efficiency will increase the power output of the engine about 14%.

When increasing supercharging boost, it is important to determine its influence on maximum cylinder pressure as well as on the ratio of maximum pressure to compression pressure. In some types of combustion systems the increase in supercharge boost results in a small incremental increase in maximum pressure over compression pressure. In certain types of divided-chamber engines, the ratio of maximum pressure to compression pressure is lower at high supercharge than in normal aspirated versions of the engine. In open-chamber-type engines the peak pressures may climb to very high values at higher boost pressures. In such cases there is a limit placed on the practical value of supercharge boost as bearing problems increase and side thrust of pistons presents difficulties in lubrication.

Higher increases in supercharge boost are permissible, however, if the high-pressure stage is part of a compound system such as a gasifier as used in the Pescara free-piston engine. In this category of compound engines, high-boost supercharge is justified because of the availability of large amounts of potential energy in the exhaust for a second-stage expansion in a turbine. The upper limit of supercharge is reached when the maximum cylinder pressures are such as to cause scuffing of the piston rings, excessive liner wear, overloading of the bearings, and leakage at the cylinder heat joints due to springing of the cylinder-head bolts or joints.

There are several advantages which can be derived from supercharging. Supercharging has a tendency to reduce the ignition-delay period which permits engines to run quieter and smoother. It becomes possible to burn fuels of lower cetane value or of a lower volatility such as heavy distillates or residuals. The application of a turbine in any of its configurations has an inherent ability to broaden the fuel appetite of the powerplant of which it becomes a part. Combustion generally is improved and a somewhat higher proportion of the air can be burned effectively and with a clean exhaust. It is also noted that the relative heat losses to the cooling water diminish with the increased density of the air of combustion. The high efficiency of combustion as a result of supercharging can be readily appreciated when burning difficult fuels. By referring to Fig. 13, showing the results obtained by Sir Harry Ricardo on a $5 \times 5\frac{1}{2}$ Comet engine at 20-in. Hg boost pressure, the bmep curves extend out to 200 psi and for the major portion of their operating range are below 0.40 lb per bhp-hr in specific fuel consumption. All fuels burned were of the heavy residual type.

[11] SAE Transactions, Vol. 62, 1954, pp. 426–436: "The Free-Piston and Turbine Compound Engine—Status of Development," by A. L. London.

The gas turbine has really made possible efficient use of higher supercharge boost for piston engines, particularly of the diesel type. The field of very high turbocharging pressure ratios has hardly been touched. The piston engine itself, whether 2- or 4-stroke, must be modified in design to accommodate the maximum utilization of the highest exhaust gas energy which can be made available with a properly matched turbocharger.

Compound Power Systems

The free-piston gasifier in combination with the gas turbine as illustrated in Fig. 14 (from footnote 11), provides an ideal opportunity for utilizing high-supercharge boost in a practical system. The inherent efficiency of the cycle is high, and the pressures and temperatures reach values not attainable in the case of diesel engines but at the expense of problems in selection of materials and lubricants. The high pressures and temperatures are made possible because of various factors. The absence of bearings and connecting rods permits the use of higher compression pressures. Heat losses are small due to the relatively small surfaces of the combustion chamber. Large excess scavenging air provides cooling of the internal surfaces of the cylinder and carries the heat so accumulated into the turbine. The high compression ratio gives a higher adiabatic efficiency than a comparable diesel, and the friction losses are lower. The gas generator is well adapted to the combustion of heavy fuels because the highly supercharged power cylinder is provided with large quantities of excess air for combustion and for scavenging.

The performance characteristics of the Muntz free-piston gas generator is shown in Fig. 15 (from footnote 10). This unit is based on the Pescara design of free-piston, 2-cycle configuration. The specific-fuel-consumption curve and the other data all refer to the gasifier unit and are not specific to the overall performance of the combined turbine and gasifier. The specific-fuel-consumption curve of the gasifier does reveal the excellent economy obtained in a normal load range but reveals a relatively high-fuel consumption as the unit approaches idling. This situation has been considerably improved by the recent developments of the General Motors

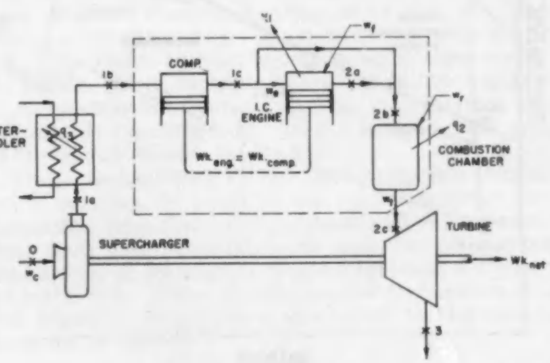


Fig. 17—System diagram of compound engine.

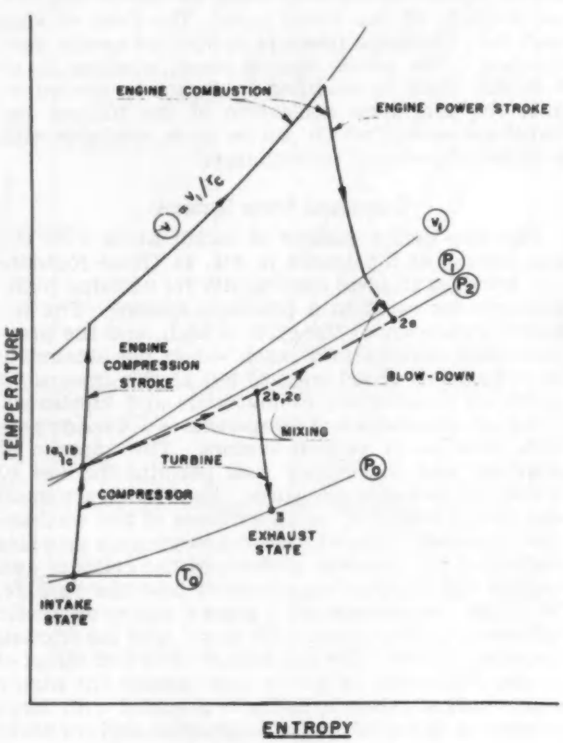


Fig. 18—Process representation of simple cycle.

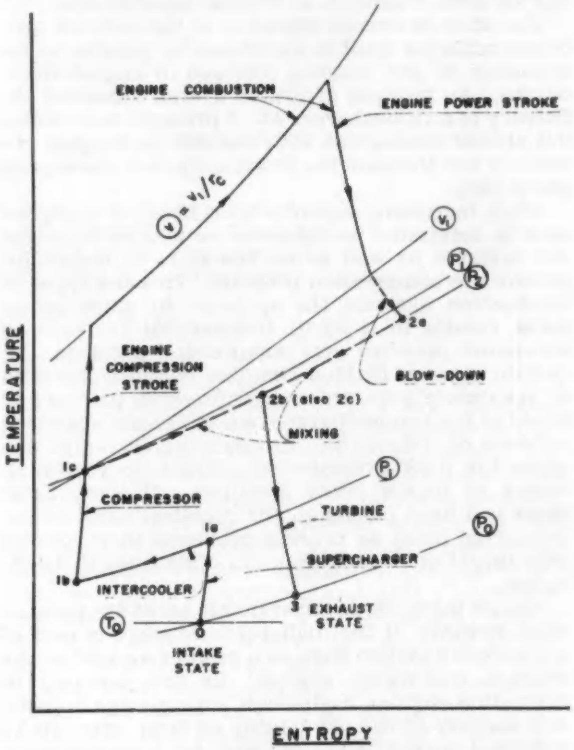


Fig. 20—Process representation of supercharge and intercooled cycle.

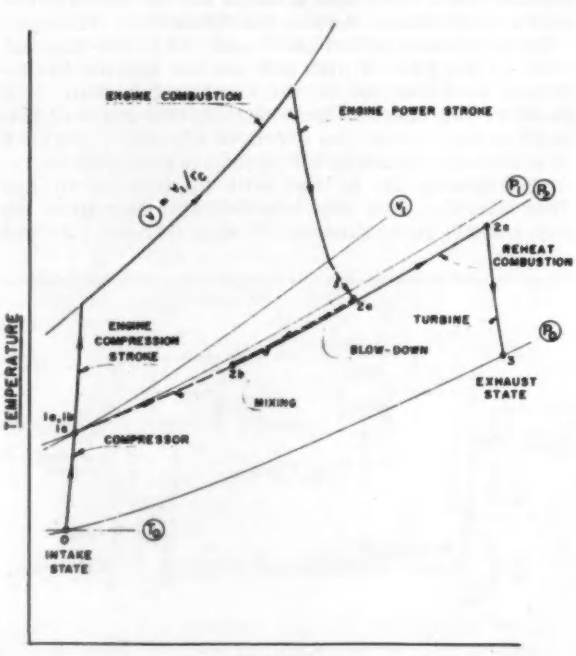


Fig. 19—Process representation of reheat cycle.

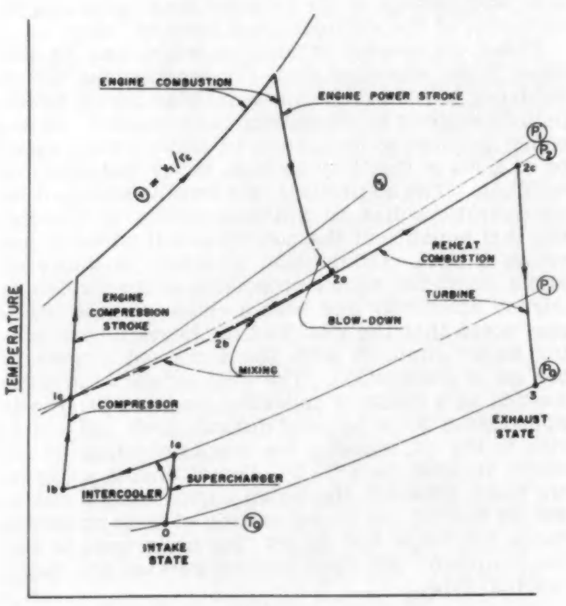


Fig. 21—Process representation of supercharge, intercooled, and reheated cycle.

"Hyprex engine," as reported by Gregory Flynn[12] by a rather novel system of recirculation. By recirculating air through a valve from the gasifier airbox, it is possible to maintain sufficient stroke to uncover the ports at low loads. This provides significant improvement in free-piston performance and makes it more attractive to locomotive and vehicle installations where considerable low-load operation is necessary.

In some quarters there has been an objection raised to the use of the reciprocating-type compressor which has been dictated by the free-piston gas-generator design. The reciprocating compressor presents difficulties in dimensions when considering the use of the free-piston compound engine in aircraft or in some other military installations. As an alternative, a gas generator consisting of a reciprocating crankshaft engine driving a rotary compressor has been considered by some development laboratories. The Napier Nomad engine, Fig. 12, utilizes a gas-turbine-driven axial-compressor which as a unit is geared to the main driveshaft of the engine. This system has been under intensive development by Sir Harry Ricardo in Britain, principally for aircraft applications. This development utilizes the gas-generator engine as a source of large quantities of excess air and operates on the compression-ignition principle using the 2-stroke, loop-scavenge cycle. The performance of this engine has justified the enthusiasm of its proponents as revealed in the performance curves of Fig. 16 (from footnote 10) obtained from the Nomad engine. The fuel-consumption curve is extremely attractive, and its general characteristics are very satisfactory within the operating range of an aircraft powerplant. The various allocations of power, as distributed from the engine to the compressor and with the additional pickup from the turbine achieves a resultant shaft horsepower approaching 3000 hp at 2000 rpm. The compound powerplant lends itself to a number of variations achieving different system performance characteristics. The optimum cycle configuration can be evaluated from a thermodynamic analysis of a general compound-engine system and its common variations.[11]

The relative merits of the simple compound cycle with the addition of reheat and supercharging lead to some interesting cycle performances. The thesis work accomplished by Cullinane and Wilcox at Stanford University[13] reveals some significant advantages. Fig. 17 (from footnote 13) shows a system diagram for a compound engine. The output of the internal-combustion engine is designated as gas horsepower and made available as energy for utilization. The gas horsepower is proportional to the produce of the mass flow of gas and the adiabatic heat drop. This is expressed in the formula as follows:

$$\omega Q_\Delta = \omega C_p T_2 \left[1 - \left(\frac{P_0}{P_2} \right)^{\frac{k-1}{k}} \right]$$

[12] "Observations on 25,000 Hr of Free-Piston-Engine Operation," by Gregory Flynn. Presented at SAE National West Coast Meeting, San Francisco, August, 1956.

[13] "Thermodynamic Analysis of the Supercharged, Intercooled, and Reheat Compound Engine Cycle," by J. F. Cullinane and R. E. Wilcox. Thesis presented at Stanford University.

where:

ω = Mass flow of gas, lb per sec
Q_Δ = Adiabatic heat drop, Btu per lb
C_p = Specific heat at constant pressure
T_2 = Gas-delivery temperature at two atmospheres, R (Fig. 17)
P_2 = Gas-delivery pressure, psia at two atmospheres (Fig. 17)
P_0 = Atmospheric pressure, psia
k = Ratio of specific heats

From this equation it can be seen that the gas horsepower is principally dependent upon the gas delivery temperature T_2 and the gas-delivery pressure P_2. The variations of C_p and k are secondary effects. The gas-delivery temperature obviously depends on the inlet air temperature to which is added the temperature rise through the gas generator. This is the adiabatic temperature rise influenced in practice by pumping and other losses so that the heat of the air at the end of compression is above its adiabatic temperature. The temperature rise is also due to the mixing of the air with the exhaust gases. This rise comes about because the air in effect picks up the heat rejected from the engine cylinder and varies inversely as the indicated efficiency of the engine cylinder. It follows that the delivery temperature T_2 rises with the delivery pressure P_2. The gas horsepower delivered by the heat generator or gas generator assumes an adiabatic expansion of the gases from the gas generator delivery pressure at atmospheric pressure. To obtain the useful shaft output horsepower, the gas horsepower must be multiplied by the efficiency of the turbine, the efficiency of the reduction gear, and by other intermediate efficiencies due to losses in the power train. The gas horsepower available at two atmospheres is subject to a number of variations as expressed by the inclusion of components shown in the system diagram of Fig. 17.

These variants are expressed by the following figures. In Fig. 18 (from footnote 13) we have the process representation for a simple cycle. This is modified in Fig. 19 (from footnote 13) by reheat. Here the area involved in the temperature-entropy diagram is considerably increased as revealed for a specific problem study. Again, one may consider the application of turbocharging and suitable intercooling. This is represented in a cycle diagram of Fig. 20 (from footnote 13) and reveals a smaller area diagram than that obtained in Fig. 19. This use of supercharging in the arrangement shown in Fig. 17 has been subject to considerable controversy. In Fig. 21 (from footnote 13) we have the addition of the elements of supercharging, intercooling, and reheat. It represents by far the largest cycle area of the group chosen for study.

These comparisons of the various cycle performances can readily point to the optimum cycle configuration for a given design condition. These analyses were made regardless of how the compressor was driven or by what means compressed air might be furnished. These studies resolve themselves into the following conclusions as related to the system diagram of Fig. 17.

1. The simple cycle gives the lowest specific air rate and specific fuel consumption with the highest cycle efficiency when the design considers constant

maximum power output where inlet turbine temperature is the design limitation.

2. Supercharging by the centrifugal compressor, as shown in Figs. 17 and 20, has an advantage in reducing the size of the reciprocating components or in boosting the cycle pressure ratio above that possible with a reciprocating compressor. Supercharging by this means results in a higher specific air rate and specific fuel consumption and a lower cycle efficiency than the simple cycle.

3. Where design limitation is the cycle pressure ratio, reheat as in Fig. 19 will give a lower specific air rate than the simple cycle, but at the expense of higher turbine inlet temperature, higher specific fuel consumption but yielding a lower cycle efficiency.

4. A design involving a simple cycle for the part-load power requirements but incorporating reheat to provide peak power, as in Fig. 19, will provide a configuration which is the smallest in dimensions but most economical.

In practice, since the exhaust gases from the gas generator contain about 75% of the original oxygen, a simple reheat combustion chamber can be included between the gas generator and the turbine. The power may be increased approximately 33% for an increase in total fuel consumption of 10%.

Problems in Utilizing Nuclear Energy for Vehicle Power

The marriage of the engine of the future with the fuel of the future was described by Dr. J. J. McMullen, chief of the Office of Construction and Repair of the U. S. Maritime Administration as a highly desirable combination. He has said: "Gas turbines now appear to be the ideal power takeoff for the nuclear reactor, and they seem to be married to each other, the atomic reactor supplying energy and the gas turbine supplying the mechanical power. The gas-turbine atomic powerplant takes up less space and operates at a higher efficiency than do powerplants run on water or fossil fuels."

In the various nuclear powerplants[14] now under construction in our country as public-utility powerplants, the steam turbine has been the principal source supplying mechanical power. It is expected that by 1970 about 25% of all public-utility powerplants will be nuclear powered.

The flow diagram of a proposed 200-kw gas-turbine reactor powerplant by Gallagher[15] shows values of temperatures and pressures for an open-cycle system (Fig. 22—from footnote 15).

In the arrangement, the gas-cooled reactor replaces the conventional combustor or air heater in the gas-turbine system. Solid moderators and Army-package reactor-type stainless-steel fuel elements are employed. Replacing the combustor with a gas-cooled reactor has the effect of reducing the expansion ratio across the turbine because of the pressure drop across the reactor and the back pressure from the filter and exhaust ducting.

The open-cycle reactor system is chosen for its lightness and small dimensions and relative simplicity. Its application at low-power levels is particularly promising.

It should be emphasized that numerous technical problems need to be solved before a gas-turbine reactor powerplant can be constructed and operated. According to Gallagher: "These problems should not be underestimated, but present indications are that they surely can be solved."

With regard to the use of nuclear power in vehicle powerplants, its feasibility at the present is rather questionable. Some studies which have been developed by the Westinghouse Electric Corp. and the University of Michigan on the use of nuclear energy for automotive propulsion indicate that with the present technology the powerplants alone would weigh at least 25 tons. The most serious disadvantage of the nuclear powerplant today is the requirement for approximately 20 lb of shielding material per horsepower output from the nuclear-heat source. This fact alone places a heavy responsibility on research activities. This is needed to achieve a major breakthrough in new shielding materials or better shielding methods so as to reduce overall weight before consideration can be given to the application of nuclear power for automotive-type propulsion. There have been some estimates that military equipment of over 70-tons weight could well consider possibilities in nuclear-power development.

At the present time there are severe temperature limitations which reduce the efficiency of conversion of heat energy to mechanical energy by the nuclear-power method. Materials required by the nuclear reactor are not, at present, the conventional engineering materials in common practice. Corrosion resistance, strength, ductility, mechanical and thermal stress, and thermal properties are necessary in the materials for thermal reactors. The higher operating temperatures, the fuel inventory, and the economic parameters place new and critical demands on material. Here again, the metallurgist has a tremendous opportunity to assist in achieving early breakthroughs. The Atomic Energy Commission's Coordinating Committee on Atomic Energy has made the following report:

1. Nuclear energy applied to the propulsion of merchant ships could become a significant source of power within 10 to 15 years.

2. Nuclear powerplant systems for aircraft are technically feasible in terms of foreseeable technology for military application. For commercial application they do not appear likely for many years.

3. Nuclear powerplants for locomotives are now technically feasible, but economically, locomotive powerplants competitive with the diesel locomotive and the gas turbine are not foreseeable.

4. The use of atomic-power propulsion for military vehicles and tanks requires major technological breakthroughs not now in sight.

From this it can be ascertained that the factors limiting the use of nuclear energy for vehicle propulsion are the requirements for new engineering materials, improved heat transfer, conservation of neutrons, size of reactor vessels, and equipment. These, coupled with the neutron and radiation shielding, require structures of massive weight.

It is considered possible to develop a small light-

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[14] "Dresden Nuclear Power Station," by T. G. LeClair. Presented at ASME Diamond Jubilee Annual Meeting, Chicago, November, 1955.

[15] *Mechanical Engineering*, Vol. 78, July, 1956, pp. 608–611: "Small Gas Turbine Reactor Plants," by J. G. Gallagher.

weight nuclear powerplant in the gas-turbine category; however, the size and weight of the shielding materials surrounding the engine are comparatively enormous. As a consequence the weight of the entire equipment associated with the nuclear-heat-power source is of paramount importance. Progress in the development of nuclear-power engines for atomic propulsion depends, to a large extent, on achieving new types of reactor fuels, new types of reactor containers, new types of coolants and working fluids for heat engines, and new types of materials for shielding radioactivity.

Solar-Energy Potentials

The world demand for energy has risen at such tremendous rates that with the close of World War II new forces have begun to exert unseen influences upon the energy situation. Fossil fuels and nuclear fuels will become increasingly scarce and expensive. Although the world will not suffer a shortage of fuel in our generation, it is quite conceivable that our descendants cannot continue indefinitely to have all the fuel that they need.

The rapid increase in population and the still more rapid increase in demands for electricity and other forms of power throughout the world place a challenge before thoughtful people as to our solemn responsibility for the needs of future generations. One is significantly impressed by the fact that nearly 2000 times as much energy as is needed for our daily power requirements falls on the geographical area of the United States, and this is the highest energy-consuming country in the world. Even though we have no practical means for utilizing solar energy, it has commanded the attention of mankind for ages. From the days of ancient Nineva to the present, courageous engineers have utilized the energy of the sun in various interesting applications. The means for generating useful power from solar energy came only after the development of the steam and hot-air engines. It may be of interest to note that John Erickson, the prolific Swedish inventor, sold more than 6000 caloric engines utilizing the energy from the sun for small power applications. In 1883 he built a rather formidable steam plant, utilizing a reflector which concentrated radiations from 23,400 sq in. of surface and produced sufficient heat to generate power from a steam engine of 6-in. bore by 8-in. stroke at 35-psi steam pressure.[16]

The work of Hoyt C. Hottel,[17] as shown in Fig. 23 (from footnote 17), exhibits some interesting factors obtained at El Paso, Tex. The energy available at various collecting temperatures exhibits a significant potential. These experiments led to the conclusion by Hottel that, "Operation at temperatures in the low-pressure steam range is entirely feasible."

The solar engine invented by John Ericsson (Fig. 24, from footnote 16) has some interesting possibilities in relation to the development of new fluids and newer methods of conversion to mechanical energy. The experiments by General Motors in developing a model miniature automobile operated by solar energy and the significant work accomplished by Bell Laboratories on utilizing solar energy for producing electricity all lead to the concept that some breakthroughs are possible where utilization of solar energy may some day be a pertinent factor for vehicle operations.

Harold Heywood exhibited, in a paper on solar-energy applications before the British Association for the Advancement of Science in September, 1953, a gas-turbine application. From this study he came to this conclusion: "The possibilities of using solar energy must be examined impartially against the background of future developments in the fuel-supply situation and the present economics must not be stressed too greatly. Over optimism is as great a

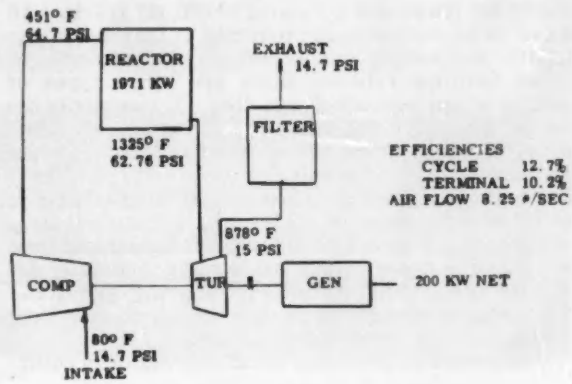


Fig. 22—Open-cycle reactor powerplant.

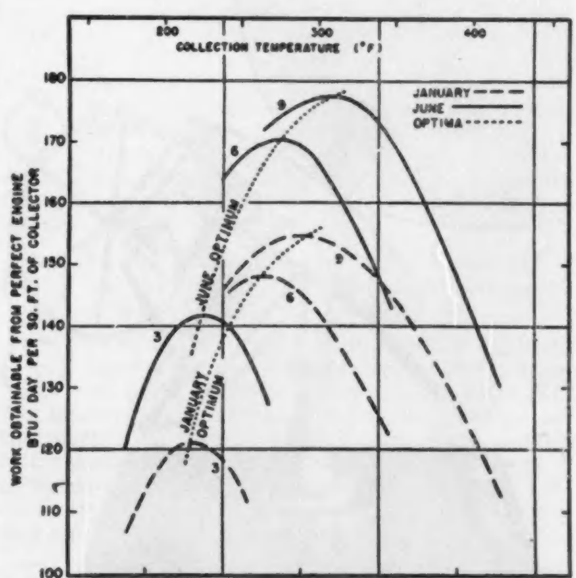


Fig. 23—Work output of solar collector-heat engine combination.

[16] "Power from Solar Energy," by J. I. Yellott. Presented at ASME Fall Meeting, Denver, September, 1956.

[17] See pp. 85–90: "Power Generation with Solar Energy," by H. C. Hottel, in "Solar Energy Research," edited by F. Daniels and J. A. Duffie. Pub. by University of Wisc. Press, 1955.

danger as undue pessimism, for it is clear that applications in the near future are limited, although the potential applications are significant. As fuels become scarcer and costlier, so will the economic balance become more favorable and experience gained now may prove of the greatest value in the future."

Engineering Challenges in Earthmoving Applications

I would be remiss if I neglected to include some indication of the impact of the earthmoving industry on our civilization and to point out the economic opportunities and the engineering challenges which they present to the young engineer.

A review of the wide and diverse application of power equipment in the off-the-highway vehicle industry points out the rapid growth of this industry over the past 25 years and the still larger growth to occur in the next quarter century.

Our "Nation on Wheels" has a giant horde of some 48,000,000 passenger cars and 10,000,000 trucks and buses as keystones in the pyramid of transportation might, supporting our economy. In addition to these familiar vehicles there are other types of mobile equipment which one does not commonly see on the highways, but yet without which the attainment of the Golden Age of Mechanization, in the Twentieth Century, would have been delayed. These are broadly classed as off-the-road equipment and cover a wide range of machines. In this category the largest group of machinery is designed and used primarily in the construction industry generally described as roadbuilding and earthmoving operations. The total value of this equipment which was built and sold in 1953 was $1,000,000,000.

The second largest class of off-the-highway equipment finds its application in mining and quarrying operations. The third class is that equipment used in agriculture for farm construction, clearing, drainage, irrigation, terracing, and tilling.

The balance, or about 35% of the construction-machinery industry's production goes to such industries as petroleum production, logging, materials handling, transportation and utilities, commercial construction, and military construction.

Off-the-highway machinery specially designed for road-building and earthmoving operations includes such self-propelled units as crawlers and wheel tractors, motor graders and scrapers, trenchers, trucks, cranes, shovels, and rollers. Implementing this equipment is a long list of attachments, tools, and specially designed equipment applicable for particular functions and operations.

Mining and quarrying make wide usage of construction machinery such as cranes, shovels, and draglines for stripping, loading, stockpiling, materials handling, and erection purposes. Crawler tractors and allied equipment, for example, come into play for land clearance, removal of overburden, road construction, and materials handling. Motor graders build and maintain access and haulage roads, remove snow, and perform other vital operations in open pit and other types of mining. Wheel tractors and scrapers remove overburden, and handle bulk materials in numerous ways.

Agriculture in the U. S. today is big business with an estimated "plant" value of about $157,000,000,000, or a national average worth of $30,000 per farm. With increased agriculture mechanization, an increase in productivity of farm labor and standard of living for the American farmer has resulted. In 1953, for example, farm output averaged 44% above the period 1934–1939. This increased productivity in 15 years resulted from the use of nearly 90% more power and machinery on farms.

The development trends outlined here will probably have their first application in off-the-highway vehicles. Such vehicles can be designed to exploit the full advantages of the turbine in its various configurations. These advantages include: (1) reduction of weight and bulk, (2) use of available low-cost fuels, (3) operation in any climate, and (4) low maintenance.

Conclusion

The author is well aware of the challenges in the Buckendale Lecture "where the lectures are directed toward filling the needs of young engineers and students for up-to-date practical knowledge." It is realized that the author has not evaluated solution of problems but rather has indicated challenges which could be of stimulation to the college graduate and the young engineer in industry. The young engineer can easily become quite enamored over the fantastic projects which our era presents to him; however, he must not lose sight of the fact that the great automotive industry has potentials equally as significant and pertinent. The role of the turbine is most inviting. The future of transportation and communications are definitely enmeshed in the successful applications of the turbine to automotive utilization. The progress of technology and the achievement of a higher standard of living will be prominently influenced by the impact of the turbine on our era.

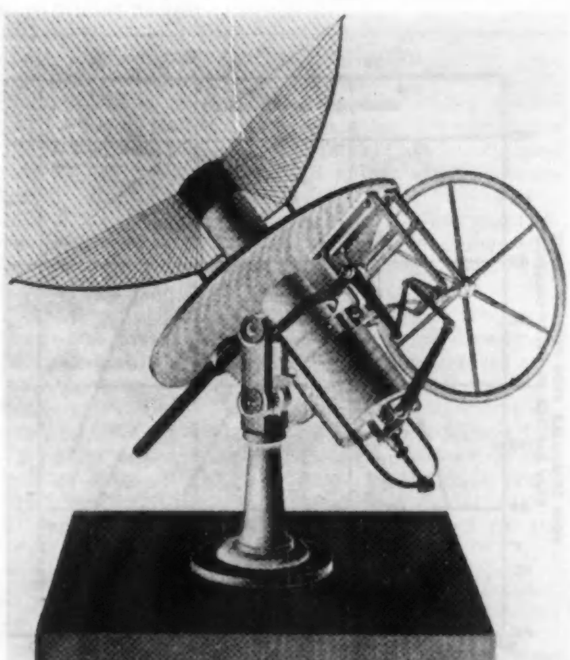
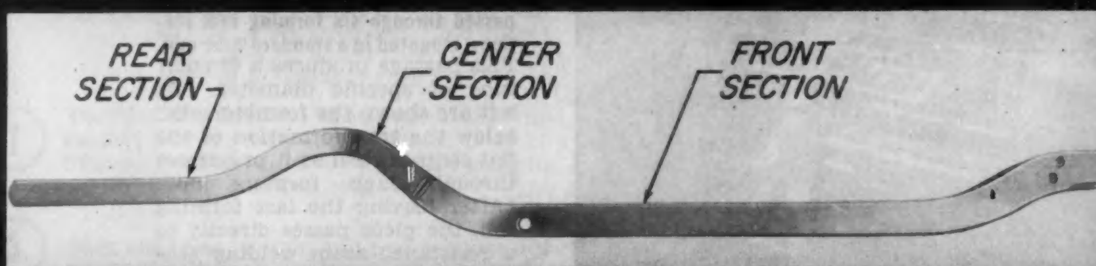


Fig. 24—John Ericsson's solar engine.

Unique Methods Produce Side Rails for Chevy Frame



New techniques were developed to manufacture this 3-section side rail of the Chevrolet frame. Ready for the 1955 model, this design resulted from 14 months of close cooperation between design and manufacturing engineers prior to going into production.

Godfrey Burrows, Chevrolet-Flint Frame and Stamping Plant, GMC

Based on paper "New Techniques of Automobile Frame Manufacture" presented at the SAE Summer Meeting, Atlantic City, June, 1956.

CHEVROLET produces a rectangular side rail for its frame from a circular tube by unique manufacturing processes. Major problems were solved in development of each of a dozen steps. Many of them are definite departures from conventional methods.

Usually a rectangular rail is produced by using two over-lapping channels, joined by submerged arc welding. But Chevrolet produces its rectangular side rail from a circular tube by the following sequence of manufacturing operations:

1. First, a flat strip of steel is passed through six forming roll stations, mounted in a standard tube mill, to produce a circular tube of specific diameter (Fig. 1). (The tube passes directly from the last forming roll to a resistance seam-welding station.)

2. The tube is seam-welded as it passes from right to left through the last forming roll. (Pressure and guide rolls support the tube as it is welded by two rotary welding electrodes at a maximum speed of 150 rpm.)

3. Next, the circular tube passes through a series of four sizing rolls before entering a "turks head"—a unit of tooling in the form of rolls and consisting of two stations, each having four rolls ground to desired face contour (Fig. 2—left).

4. Passing through the turks head, the tube is transformed from a circular to a rectangular section (Fig. 2—right).

5. Then a "flying saw" unit cuts the continuously moving rectangular rail emerging from the turks head. It cuts the rail to the specified length (204 in. for the front section; 204 in. for the rear). The flying saw unit clamps the moving rail, travels with it, and, during the travel, cuts it to exact lengths. After cutting, the saw unit returns to its original position to again clamp the rail and repeat the cut-off operation (Fig. 2).

6. Next comes the transposing of the front, rear, and center sections of this side rail (Fig. 4).

(A) The forward end of the side rail's

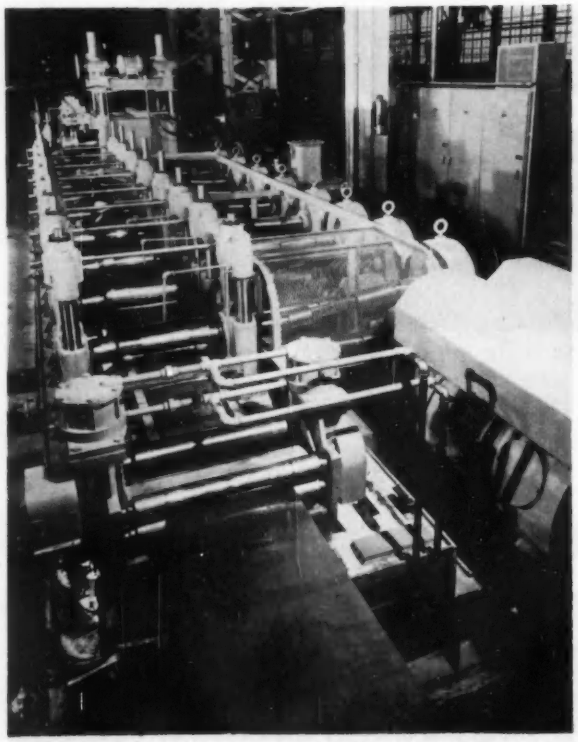
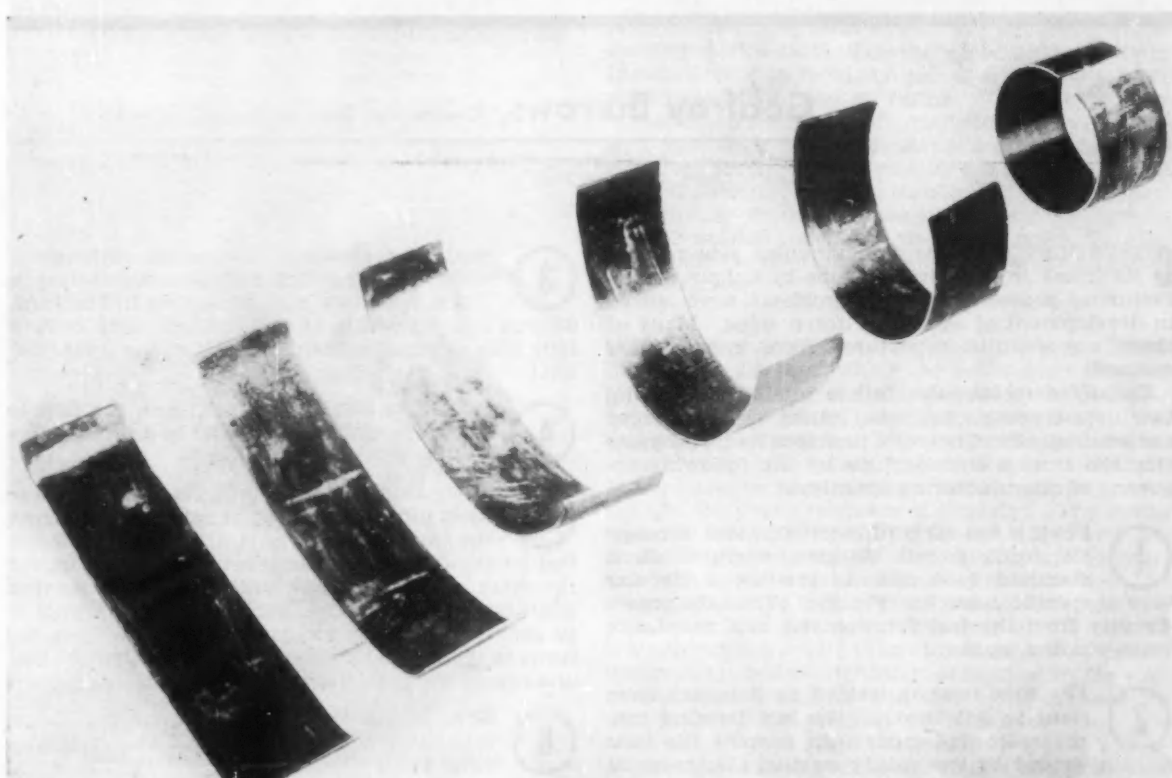


Fig. 1—MANUFACTURING BEGINS when a flat strip of steel is passed through six forming mill stations, mounted in a standard tube mill. This passage produces a circular tube of specific diameter. **At left** are shown the forming rolls; **below** the transformation of the flat strip of steel as it progresses through each forming mill. (After leaving the last forming roll, the piece passes directly to a resistance seam welding station.)



front section is transposed from a width and depth of 4.00 × 4.50 in. to 2.88 × 5.62 in. by two individual expanding tools. (These tools are mounted in a specially-designed, hydraulically-operated production machine built to achieve the transposition operations (Fig. 5).

This front section requires five bending operations, performed in the sequence shown in Fig. 6.

(B) The rear section, on the other hand, requires but two bends.

(C) The center section of the side rail is fabricated from left- and right-hand pressed-metal stampings submerged arc-welded together.

7 The next steps are (a) to size accurately the mating ends of each section which is to be joined to another and (b) insert a spacer in the end of each mating section (Fig. 7).

8 Then the front, center, and rear sections are joined together by resistance flash welding.

9 After welding, the frame passes to a piercing operation, where holes are pierced simultaneously in all body brackets by hydraulically-operated C-type equalizing guns. These guns

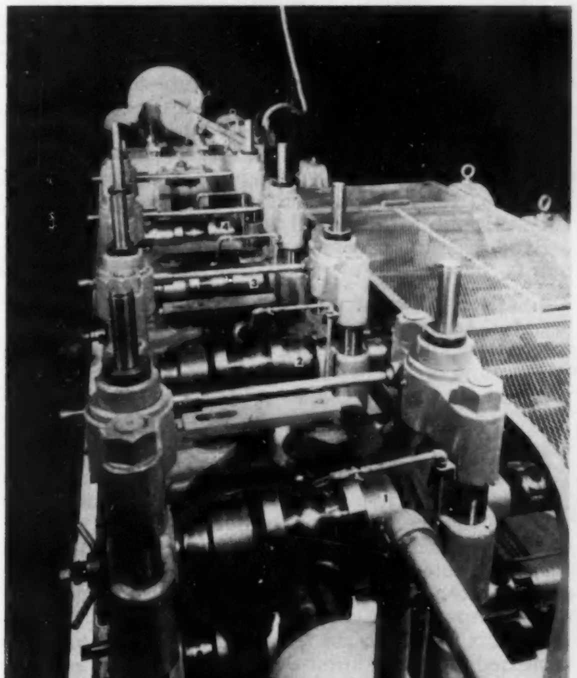
THIS ARTICLE tells how some unique manufacturing processes were arrived at to produce the rectangular side rail of Chevrolet's frame from a circular tube.

It outlines the sequence of operations finally set up. . . . Then it goes on to detail major problems encountered and to tell why they were solved the way they were.

The author is convinced that "the product designer and the manufacturing process designer are equally dependent upon each other for survival in this increasingly competitive era." This particular frame design, started 14 months prior to the introduction of the car on which it was to appear, was finalized, he says, "after much discussion and joint effort on the part of engineers engaged in both the engineering and manufacturing aspects of the development program."

Complete paper on which this article is based is available in multilith form from SAE Special Publications Department, 485 Lexington Ave., New York 17, N. Y. Price: 35¢ to members; 60¢ to nonmembers.

Fig. 2—**TRANSFORMATION FROM TUBE TO RECTANGULAR SECTION takes place in a "turks head" unit, after welding has been completed.** This unit consists of two stations, each having four rolls ground to the desired face contour to change the tube to a rectangular form with the desired dimensions. **At left**, the tube is shown passing through the series of four sizing rolls before entering the turks head. **At right**, the tube is emerging from the turks head.



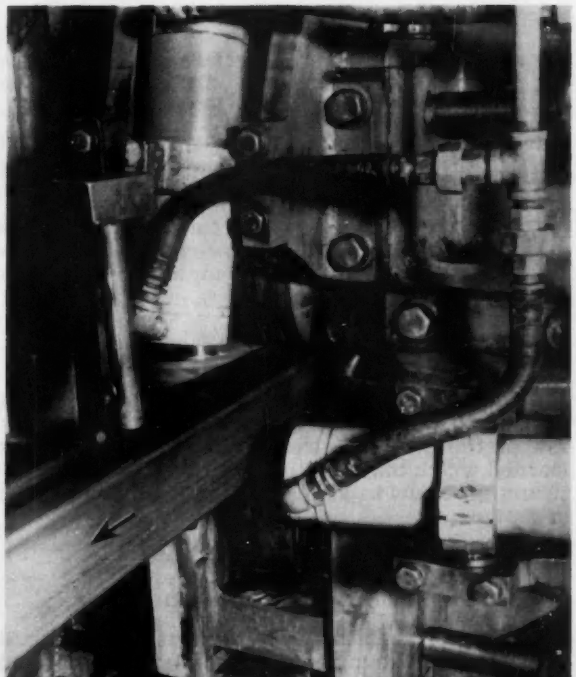
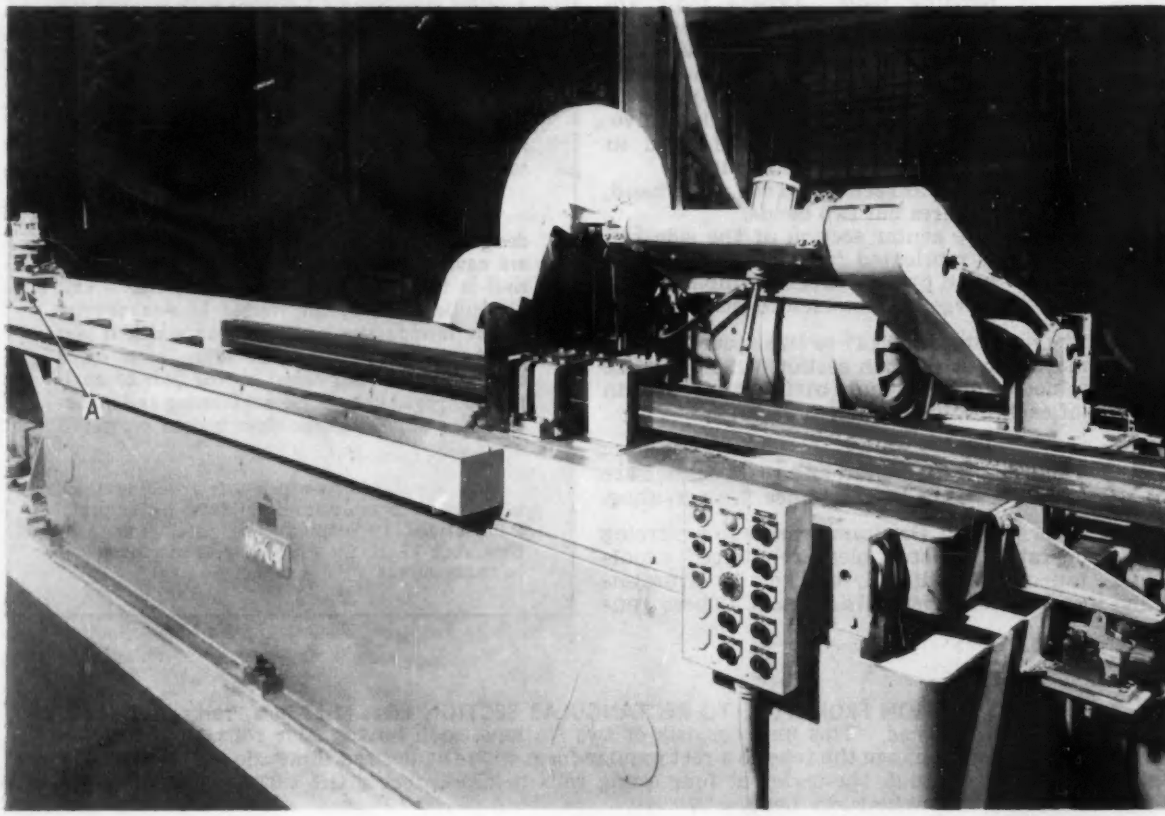


Fig. 3—A "FLYING SAW" cuts the rail to specified lengths as it emerges continuously from the turks head (see Fig. 2). This saw unit clamps the moving rail, travels with it, and cuts to exact lengths during travel. . . . Then it returns to its original position and does the same thing over again.



are accurately located on a specially-designed piercing fixture. The frame is rigidly mounted in locators positioned between the C-type guns (Fig. 8).

(10) Next, the frame moves through a special three-stage washer designed to produce an uncontaminated surface prior to painting.

(11) Finally, it moves by conveyor from the washer to the final flow-coat paint operation. (Then it is ready for shipping to various Chevrolet car assembly plants.)

How Problems Were Solved

In developing these operations, major problems were met and solved. Many of the solutions, but few of the problems, were unique. So, much was learned which may help in facing similar manufacturing problems in connection with other products or designs.

Tube Mill Problems

The major problem in setting up the tube mill operation, for example, was to design forming and sizing roll equipment which could be mounted in two standard-type tube mills. Each mill had to produce from a flat strip of steel a tube of a given diameter, to be used for the front and rear sections of the side rail. Tube diameters had to be accurate from both mills. (A rectangular front section of 4.00×4.50 in. and a rectangular rear section of 2.75×3.50 in. had to result from passing a round tube through forming rolls.)

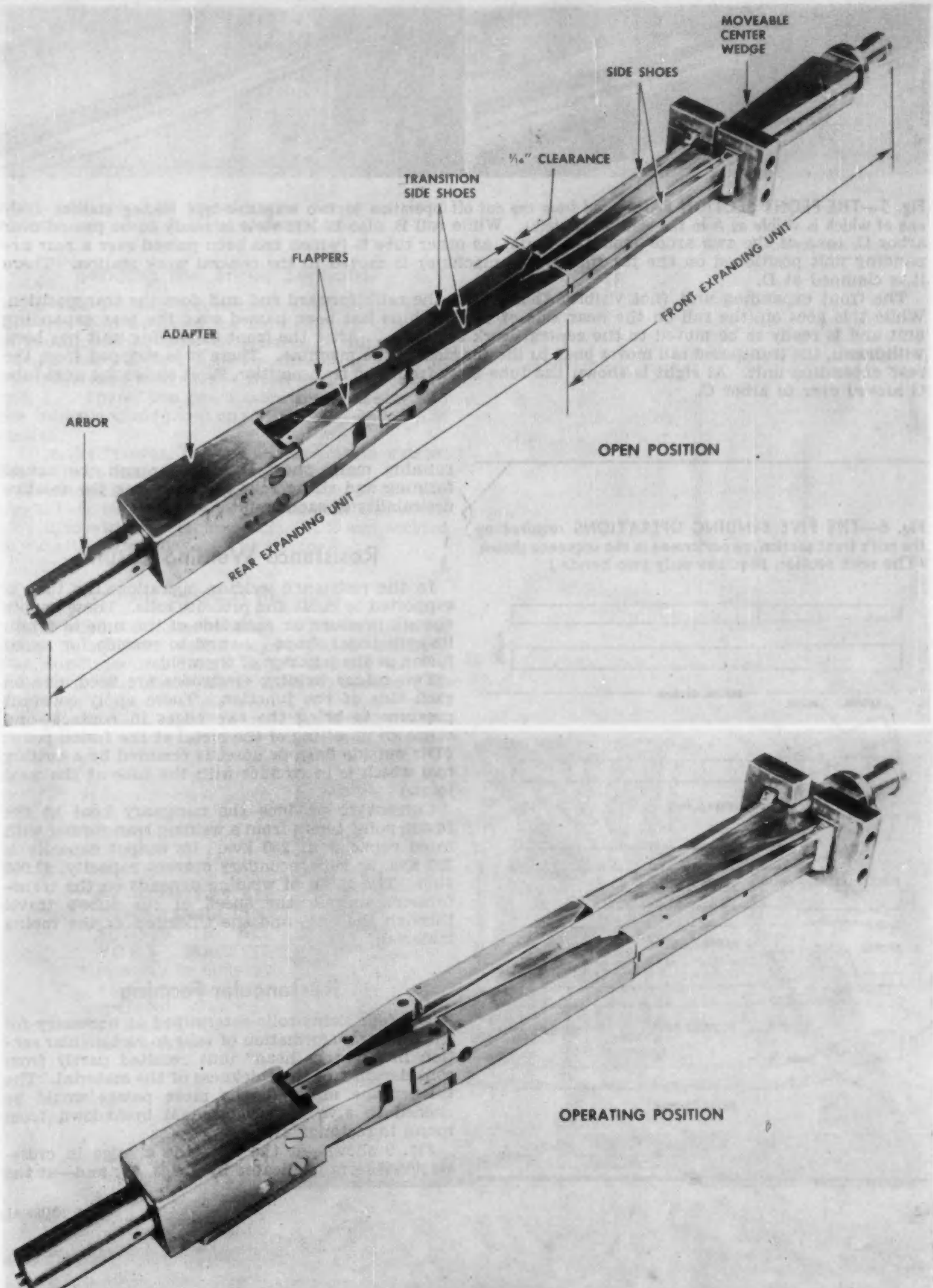
Experimental processing had to work out three points, before actual production could take place:

a. The number of passes required in the forming roll equipment had to be determined;
b. The width of flat strip steel needed to produce a tube of the desired diameter had to be determined; and
c. The amount of metal to allow for "burn off" during the resistance seam welding operation had to be decided.

In making these determinations, it had to be realized that calculations for determining the width of the steel strip would vary with the design of the forming roll equipment. (Some forming roll designs stretch the material while others have a tendency to upset or thicken it.)

The six passes or stations finally decided on were mounted in two standard tube mills. The desired width of the flat steel strip was finally determined by

Fig. 4—TRANSPOSING the front and rear sections of the rail, after they have been cut to length, involved solution of several problems described in the text. It is accomplished by two separate expanding tools. **Directly below** are shown the front and rear expanding units, their components and their relationship while in operation. **At the bottom of this page** is shown the tooling in the expanded view, just as the operation is finished.



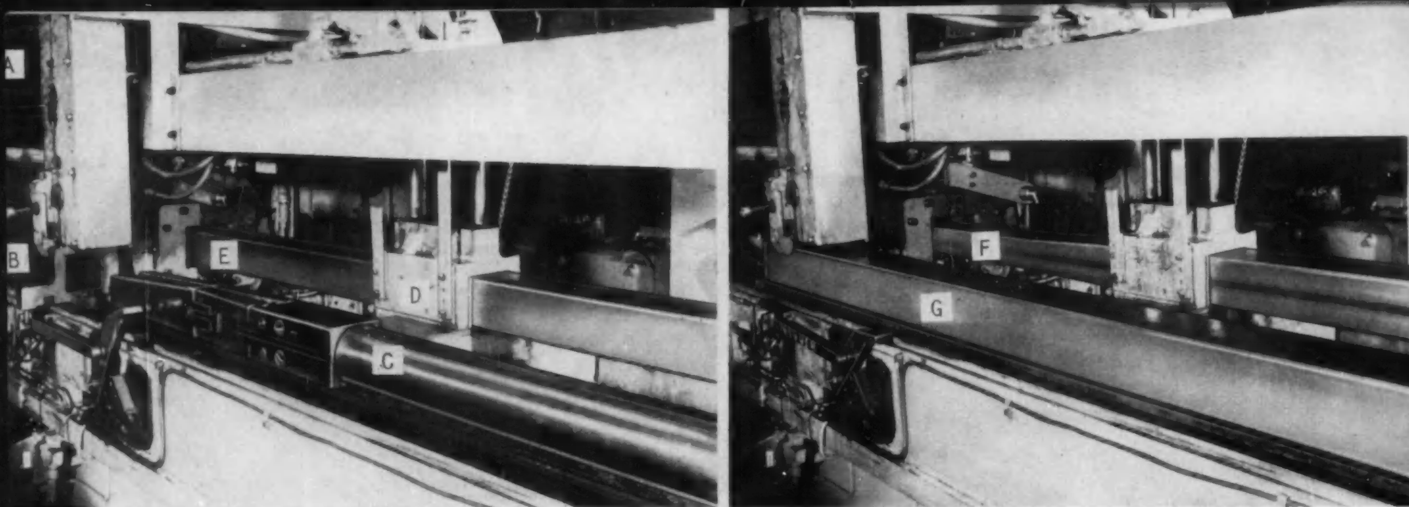
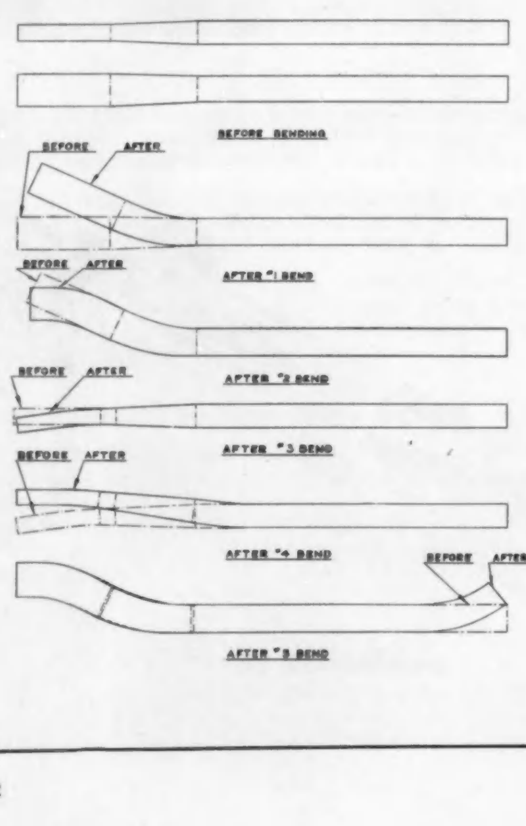


Fig. 5—THE FRONT SECTION RAIL is fed from the cut off operation to two magazine-type loading stations (only one of which is visible as A in the view at the left). While rail B, also in left view is ready to be passed over arbor C, (one of the two arbor-mounted units) as other tube E (which has been passed over a rear expanding unit positioned on the far side of the machine) is moved to the central work station. There it is clamped at D.

The front expanding unit (not visible) then enters the rail's forward end and does the transposition. While this goes on, the rail on the near side of the machine has been passed over the rear expanding unit and is ready to be moved to the central work station. . . . After the front expanding unit has been withdrawn, the transposed rail moves back to the far side of the machine. There it is stripped from the rear expanding unit. **At right** is shown the tube after front end transposition F. It shows the next tube G moved over to arbor C.

Fig. 6—THE FIVE BENDING OPERATIONS required on the rail's front section are performed in the sequence shown. (The rear section requires only two bends.)



running many short lengths through the actual forming and sizing rolls and checking the relative desirability of each result.

Resistance Welding Results

In the resistance welding operation, the tube is supported by guide and pressure rolls. These impose enough pressure on each side of the tube to retain its cylindrical shape . . . and to provide for sound fusion at the junction of the weld.

Two rotary welding electrodes are used, one on each side of the junction. These apply constant pressure to bring the two edges in contact—and cause an upsetting of the metal at the fusion point. (The outside flash or upset is removed by a cutting tool which is in contact with the tube at the weld joint.)

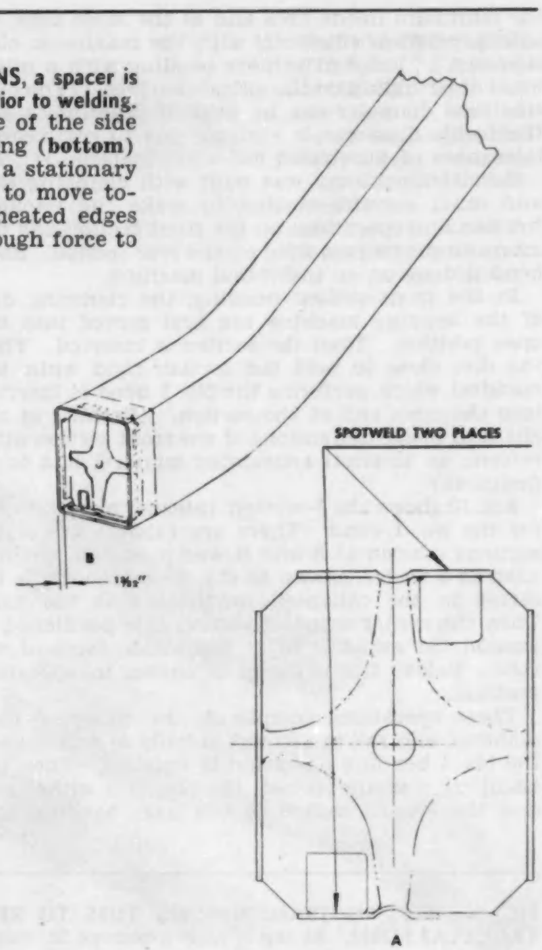
Current to produce the necessary heat at the fusion point comes from a welding transformer with rated capacity of 250 kva. Its output capacity is 200 kva, and its secondary current capacity, 57,000 amp. The speed of welding depends on the transformer's output, the speed of the tube's travel through the mill, and the thickness of the tubing material.

Rectangular Forming

The four sizing rolls determined as necessary for the final transformation of tube to rectangular section in a "turks head" unit resulted partly from consideration of the thickness of the material. The thicker the material, the more passes would be needed to give a more gradual breakdown from round to rectangular.

Fig. 9 shows—at the left—the change in cross-sectional form (indicated by 1, 2, 3, 4); and—at the

Fig. 7—IN JOINING THE THREE SECTIONS, a spacer is inserted in the mating end of each section, prior to welding. This insures maintenance of the shape of the side walls (top). The resistance flash welding (bottom) is carried out on a moving platen and a stationary platen. The moving platen continues to move toward the stationary platen until the heated edges of each rail section are joined with enough force to make a strong bond.



right—the steps in transforming the tube from round to semi-elliptical, to rectangular.

Bending the Three Sections

The cold bending operation required on the front and rear sections posed the most difficult problems in manufacturing this particular side rail.

Particularly were the bends difficult to make in the transposed area of the front section's forward end. . . . There, five bends were required—four in the transposed area and one at the rear end of the section.

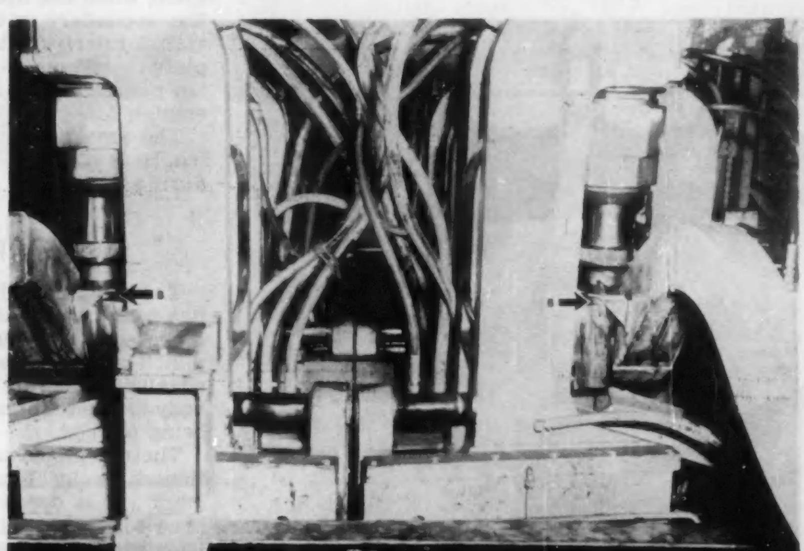
To make it even harder, no separation existed between the bends in the transposed area.

It was realized that the inside area of the rail would have to be completely (or as nearly as possible) filled with the bending tool. So, it was decided to use articulated mandrels as the tooling.

Front Section Bending

Each bend on the front section's forward end required a specially designed articulated mandrel. The same mandrel design wasn't feasible for two different bends. Each was designed to be used with

Fig. 8—HOLES ARE PIERCED SIMULTANEOUSLY IN ALL BODY BRACKETS. Piercing is done by the hydraulically operated C-type equalizing guns shown here.



"C TYPE EQUALIZING PIERCING UNIT"

the minimum inside area and at the same time, be able to perform efficiently with the maximum outside area . . . and to achieve bending with a minimum of wrinkling on the outside surface. (The outside tube diameter can be held to close limits, but the inside diameter is variable due to commercial tolerances of purchased coil-steel material.)

Special machinery was built with clamping dies and other suitable tooling to make the required five bending operations on the front section and the more-simple two required on the rear section. Each bend is done on an individual machine.

In the front-section bending, the clamping dies of the bending machine are first moved into the open position. Then the section is inserted. Then the dies close to hold the section rigid while the mandrel which performs the No. 1 bend is inserted into the open end of the section. (Because of the changed inside dimensions of the front section after reform, an internal articulated mandrel had to be designed.)

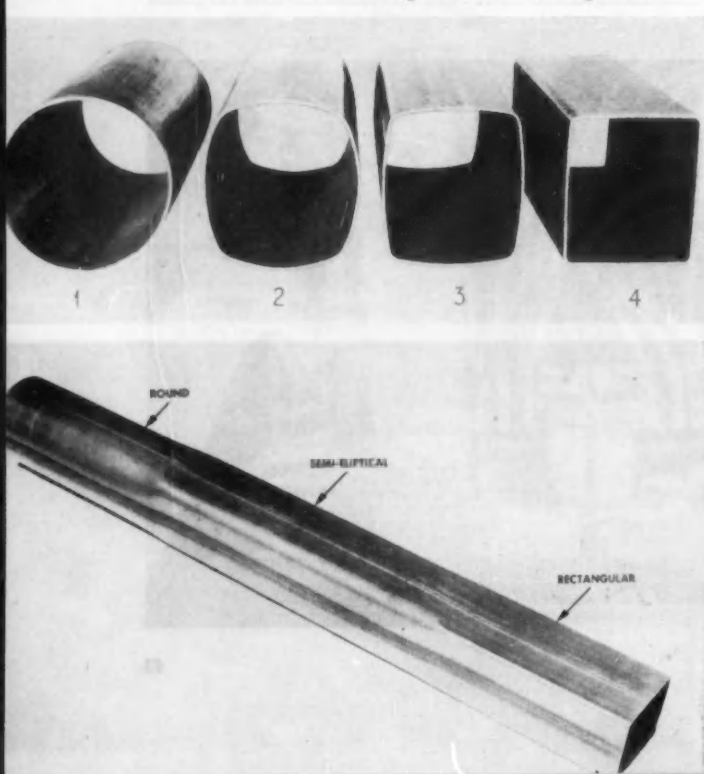
Fig. 10 shows the 3-section, internal mandrel used for the No. 1 bend. There are (above) two outer sections (shown as A and B, and a section which is used as a wedge, shown as C.) The mandrel is inserted in the collapsed condition into the tube. Then the center mandrel section C is positioned to expand the mandrel to fit the inside form of the tube. Below, the mandrel is shown in operating position.

These operations completed, the clamping dies, mandrel, and rail are moved radially as a unit until the No. 1 bending operation is finished. Then the clamping dies are opened, the mandrel withdrawn, and the section moved to the next bending machine where the No. 2 bend is performed.

The No. 3 bend on this front section is made with a mandrel whose two articulated sections are shown as C and D in Fig. 11. This mandrel must be in its collapsed position to permit insertion into the tube, as shown by A. After insertion, secondary actuation positions section C on section D, filling the inside dimensions of the tube. The working position of this mandrel is shown by B.

Prior to insertion of the mandrels, the inside walls of the rail are sprayed with a drawing compound.

FIG. 9—STEPS IN TRANSFORMING TUBE TO RECTANGULAR FORM. **At top** is shown change in cross-sectioned form; **at bottom**, the steps in transforming from round to semi-elliptical to rectangular.



Rear and Center Section Bends

The two bends on the rear section are not difficult, because the rail has the same width and depth throughout its length. Expanding-type mandrels are not required (Fig. 12).

The center side rail section, designed to form a smooth transition between front and rear sections, is formed from two pressed-metal stampings, one right hand and the other left hand, joined together by submerged arc welding (Fig. 13).

Due to the abrupt taper of this center section design, its relatively short length couldn't be expanded to the required dimensions by forming from a cylindrical tube, as with the front and rear sections. (It couldn't be expanded to the desired dimensions because of extensive stretch.)

Problems in Welding

The quality of the resistance flash welding by which the three sections are joined depends on accurate sizing of the mating ends. So, accurate checking is required.

Welding is carried out on a moving platen and a stationary platen. Each has sufficient surface area for mounting of electrodes, dies, die holders, and work locators. One section of the side rail is placed in the stationary platen and its mating section on the moving platen. At a given time in the welding cycle, when the metal has reached the plastic state, the secondary current of the welding machine's transformer is automatically cut off. The moving platen continues toward the stationary platen until the heated edges of each rail section are joined with enough force to make a strong bond.

The amount to allow for "burn off" in the rail's length is considered when the rail is cut to length during the cut-off operation.

The Piercing Machine

The machine which does the piercing operation has a number of accurately-located, hydraulically-operated C-type guns, each of which contains a punch and die mounted to a common base. The equalizing feature of each gun assures that the body bracket will not be moved out of position while being pierced.

The assembled and welded frame is rigidly positioned on locators mounted between the C-type guns. If it doesn't rest fully on all locators, the need for inspection is indicated automatically. All body brackets are pierced at the same time. Hole dimensions are held to close limits.

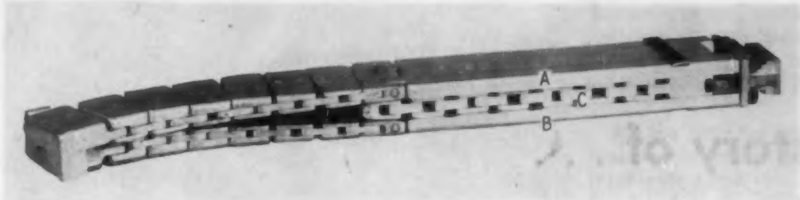


Fig. 10—THE 3-SECTION, INTERNAL MANDREL used for the first of the five bends required on the rail's front section. The mandrel has two outer sections as shown in A and B —and a section used as a wedge, shown in C.

Fig. 11—THE ARTICULATED MANDREL used to make the No. 3 bend on the front section. It is inserted in the tube in the collapsed position, A. Secondary actuation positions section C, on section D. The mandrel is shown in working position by B.

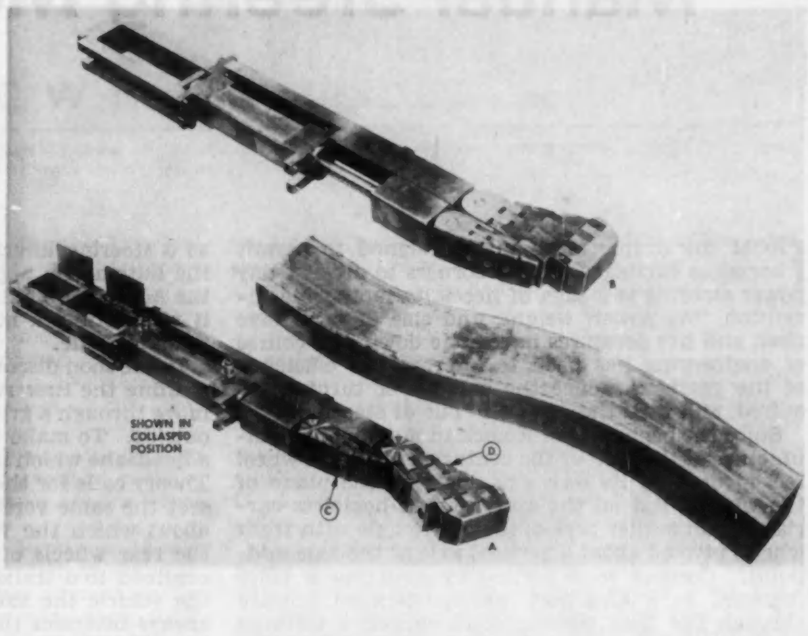
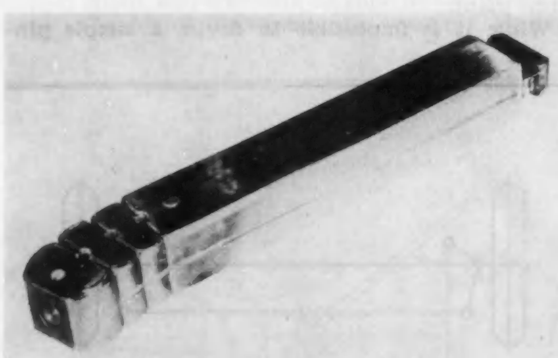


Fig.12—BOTH OF THE TWO REAR SECTION BENDS are performed by the same articulated mandrel.



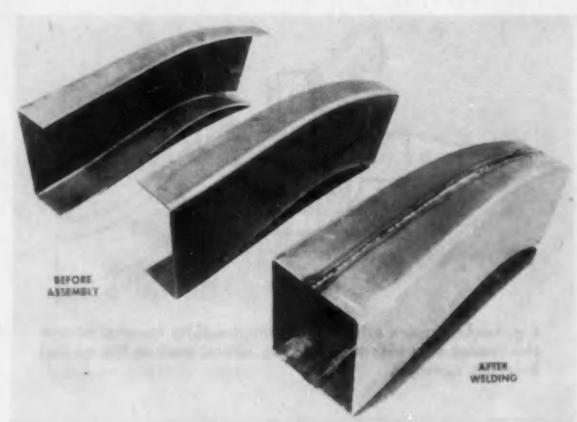


Fig. 13—THE CENTER SECTION is formed from two pressed-metal stampings, one right hand and the other left. They are joined by submerged arc welding.

A Concise Technical History of . . .

Manual Steering Mechanisms

FROM the simple mechanism designed to permit horseless carriages to turn corners to present-day power steering is a saga of necessity mothering invention. As power, weight, and size of cars have risen and tire pressures have gone down, the course of engineering has been to improve the efficiency of the gearbox, reduce the amount of turning required, and take the "wrassle" out of steering.

Since the beginning of American automobile manufacture at the turn of the century, each front wheel has pivoted on its own axis, close to the plane of the wheel. But on the aptly named horseless carriage of an earlier period, the entire axle with front wheels pivoted about a vertical axis at the axle midpoint. Corners were turned by swinging a tiller fastened to a king-post which extended upward through the floor boards. Still earlier, a German carriage maker named Lankensperger invented a non-turning axle equipped with what we now know as a steering knuckle, but it didn't catch on until the automobile appeared. Patented in England as the Ackermann axle (see Fig. 1), and still so known, it represented a marked advance and doomed the swinging axle.

It was soon discovered that making a turn without scuffing the tires required the inside front wheel to move through a greater angle than the wheel on the outside. To make a linkage to accomplish this was a headache which has not yet been completely cured. Theory calls for the axes of all four wheels to intersect the same vertical line which becomes the axis about which the vehicle turns. Since the axis of the rear wheels of all conventional automobiles is confined to a transverse plane, in the plan view of the vehicle the axes of the two front wheels must always intersect the axis of the rear wheels at the same point.

While it is impossible to devise a simple pin-

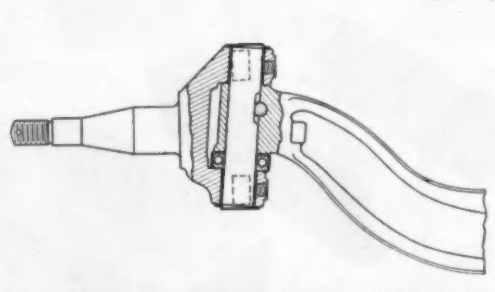


Fig. 1—Ackermann axle with steering knuckles banished forever the turning axle with non-swinging wheels used on the earliest horseless carriages.

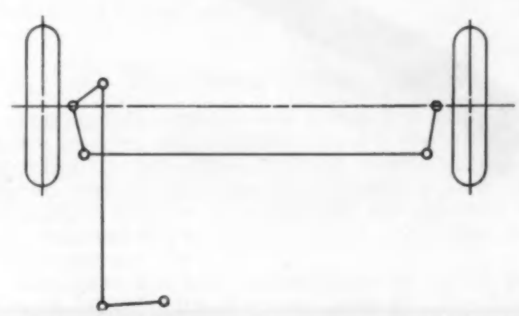


Fig. 2—Jeantaud linkage, used by a French carriage builder in 1878, is basic to all practical front-end linkages.

from 1900 to 1951

THE STORY of manual steering gears is that of continued engineering effort to increase efficiency within the gearbox, to hold down steering effort and amount of "wheeling" required as loads have gone up and tire pressures down.

As the internal combustion engine began to replace the horse, the Ackermann non-turning front axle came into its own. With increasing front-end loads, reducing gears replaced simple tiller connections between hands of driver and front wheels.

In the last few years, power steering for passenger cars has been introduced. At the start a luxury, it is fast becoming a necessity.

C. W. Lincoln, Saginaw Steering Gear Division, GMC

Paper "Steering Mechanisms and How They Got That Way" was presented at 1956 SAE Annual Meeting at Detroit, January, 1956.

jointed linkage between the two steering knuckles to accomplish this to perfection, there are approximations satisfying all practical requirements. In the basic approximation, arms attached to the steering knuckles extend rearward and toward the center plane of the vehicle and are connected together at their rear ends by a simple tie-rod. The arms are usually known as plain arms, the rod as the cross tie-rod, and the linkage is sometimes known as the Jeantaud linkage (see Fig. 2), since it was used by a French carriage builder of that name as early as 1878. All practical front-end linkages are the Jeantaud linkage or modifications of it.

With the Ackermann axle and Jeantaud linkage there remained only need for a device to transmit the steering effort from the driver's hands to the linkage. This was simple while cars were light, slow in speed, and traveling on solid or low pressure tires. The Merry Oldsmobile, for example, started out by putting a pin-joint in the middle of the cross tie-rod, and connecting in at the joint the outer end of a short arm attached to the bottom of a vertical tiller-shaft. In 1901, 400 of these cars were made with this simple modification of the Jeantaud linkage.

But cars became bigger and heavier, tires went down in pressure as their cross-sections increased, and something was needed to hold steering effort within reason. The result was the insertion of reducing gears between the driver's hands and the front wheels. With this addition, the steering gear as we think of it today was born (see Fig. 3).

Most early steering gears included a cast gearbox mounted on the vehicle frame, housing a driving and a driven gear. In many cases the gears were the well known worm and worm-wheel (see Fig. 4). The worm shaft, or steering shaft, was adapted at its upper end to receive a handwheel or steering

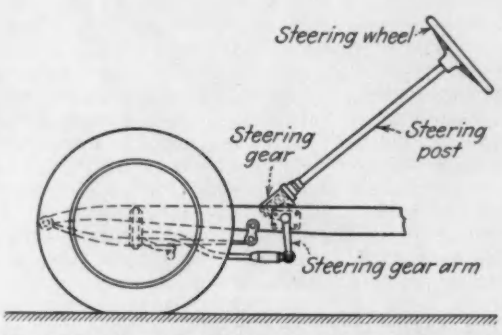


Fig. 3—Reducing gear placed between driver's hands and the wheels, was first step in trying to lessen the effort required to steer.

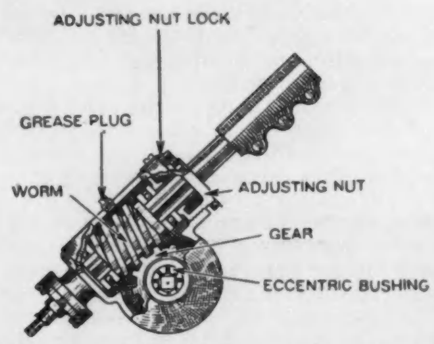


Fig. 4—Worm and worm-wheel steering gear was common among early reducing gear types. Gears were contained in a frame-mounted cast gearbox.

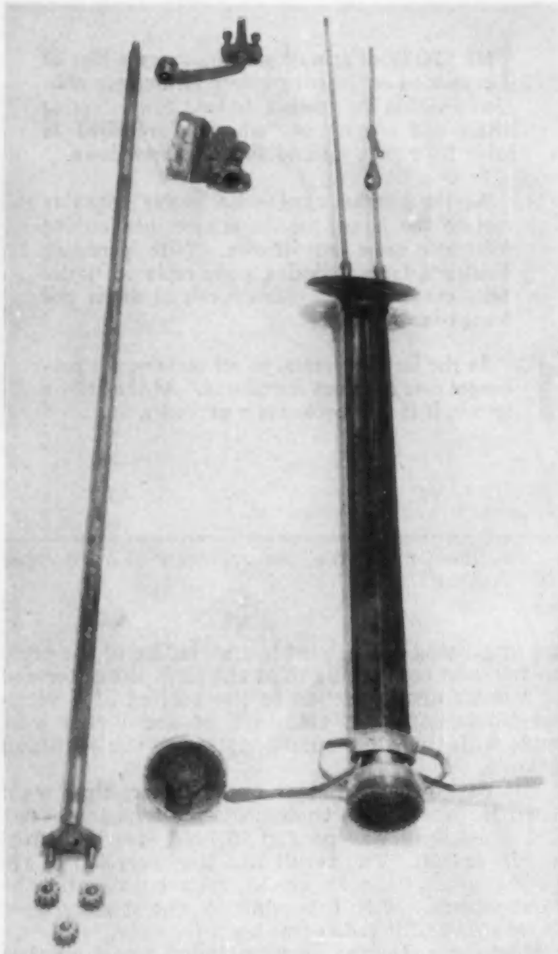


Fig. 5—Model T steering gear was the only one of its kind. Steering wheel rotated the driving member of a set of planetary gears in a small gearbox located directly below the wheel. The driven gear was fast to the shaft with ratio such as to make speed of shaft much less than that of the wheel.

wheel. The steering shaft was surrounded by a thin-walled tubular jacket fixed firmly to the upper end of the gearbox and carrying at its upper end a bearing for the upper end of the shaft. The jacket and shaft continue to this day and are often designated collectively as the steering column. The worm wheel shaft extended through the side of the gearbox and was fitted at its outer end with an arm hanging substantially downward. All steering gears were largely self-locking, or irreversible, an advantage when driving over rutted roads.

Adoption of the gearbox with its downward hanging steering arm, brought one complication to the front-end linkage and relieved it of another. Since the motion at the lower end of the steering arm was essentially fore and aft, it was necessary to equip the steering knuckle on the steering gear side of the vehicle with an extra arm extending toward the center plane of the vehicle, and to provide a link between the outer end of the arm and the lower end of the steering arm. The extra arm was known as the "third arm" and the link as the drag link. Ball joints were adopted at the ends of the drag link because motion occurred in more than one plane at each end. With steering effort transmitted to one front wheel by means of the drag link, the jointed cross tie-rod became unnecessary and the connection between the front wheels reverted to the basic Jeantaud linkage. The drag link and simple tie-rod were used for many years on most cars and continue to this day on many trucks.

By 1906, the manufacture of components for automobiles was beginning in earnest. In that year, three men in Saginaw, Mich., launched a company. David Ross of Lafayette, Ind., organized the Ross Gear and Tool Co., and the Gemmer Mfg. Co. came into being a year later in Detroit. All three concerns were making steering gears by 1908 and today produce most of those made in this country. All three made frame-mounted gears of the general type described, but there was one notable exception to this type. Henry Ford launched the Model T, in 1908, equipped with the usual steering column but the steering gear was at the top of the column (see Fig. 5).

The steering wheel on the Model T rotated the driving member of a set of planetary gears housed in a small gearbox immediately below the wheel. The driven gear was fast to the steering shaft, the gear ratio being such that the speed of the shaft was much less than that of the wheel. The steering arm was fastened directly to the lower end of the shaft, below the floor boards. The motion of the outer end of the steering arm was essentially transverse, and a transverse link was used to transmit steering effort to the knuckle on the far side of the car. This was the right-hand knuckle since the Model T was brought out as a left-hand drive car. A simple tie-rod made connection to the left-hand knuckle.

Up to 1923, steering gear development was confined largely to experiments by the three manufacturers in types of gearing for the gearbox. The first Saginaw gear had a straight worm or screw provided with crossed right and left threads. The worm meshed with half nuts on either side—one with right-hand threads, the other with left-hand. The lower end of the nuts bore against opposed ends of a rocker arm, integral with the external steering arm. Known as the "Jacox" gear (see Fig. 6), and basically of the screw-and-nut type, it was made for nearly 20 years, during which time the company was acquired by Buick and later became a GM division.

Ross, a prolific inventor, tried out many mechanisms. The most successful was basically a screw-and-nut type with various devices for converting the reciprocating motion of the nut to the oscillating motion of the steering arm. Gemmer made a screw-and-nut type, new for its day, in 1909. Gears of this basic type were to continue in use on passenger cars until well into the 1930's and they still appear on farm and industrial tractors.

From 1908 to 1923, these three companies supplied many makes of cars, many of which have since fallen by the way. Saginaw supplied among others: Auburn, Buick, Hudson, Hupp, Oakland, Packard.

Each manufacturer started out with the basic screw-and-nut type steering gear, presumably in the hope of providing something better than the well-known worm and worm-wheel type. During the 15 year period, there was a trend toward higher ratios

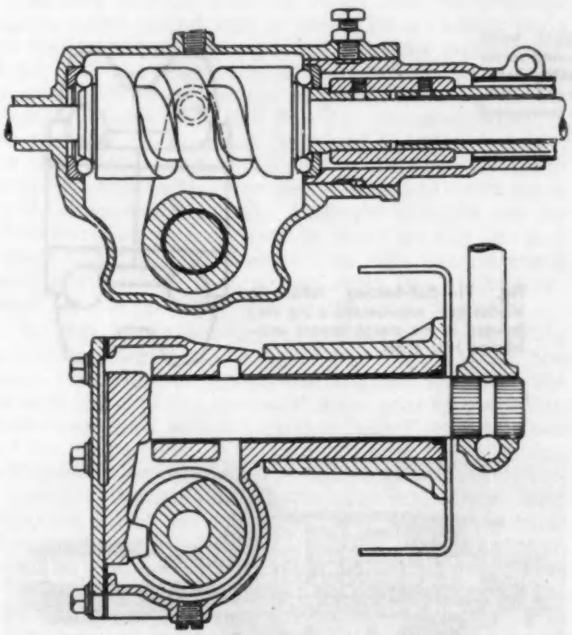


Fig. 6—"Jacox" gear was basically of the screw-and-nut type. It was manufactured for 20 years while other types were coming into use.

in steering gears in an effort to keep steering effort down in the face of car advancements. With better roads and higher speeds, the completely irreversible gear was no longer the ideal, and a change was due.

Ross made the change in 1923 with the introduction of a cam-and-lever type (see Fig. 7). It was the first on the scene and still survives on some cars. It embodied a worm or screw with a coarse-pitch thread groove, a lever on the inner end of the driven shaft or cross-shaft, which rotated in a plane parallel to the axis of the screw, and a pin in the outer end of the lever which engaged in the thread groove of the worm. The gear was unusually compact and gave a degree of reversibility. It was produced for the next five years. Meanwhile, Saginaw continued with the "Jacox" gear, but also brought out a typical worm and worm-wheel gear which was first sold to Cadillac.

There was a limit, however, to the number of turns of the steering wheel to handle a vehicle—and gearing size had to be held in reason. What was needed was more efficient gearing rather than larger gearing. This was a challenge and Henry Marles of Detroit met it by inventing the roller-tooth steering gear (see Fig. 8). It was the first to substitute rolling contact for sliding contact between major components of the mechanism. The Marles gear combined a worm of the hour-glass type with an offset roller mounted in the cross-shaft, or pitman shaft. The periphery of the roller was formed into the contour of the worm-gear tooth. Actually, Gemmer had built samples of this gear as early as 1921, but first marketed it in 1926, having acquired manufacturing rights from Marles. The roller-tooth gear was the second type of steering gear still sur-

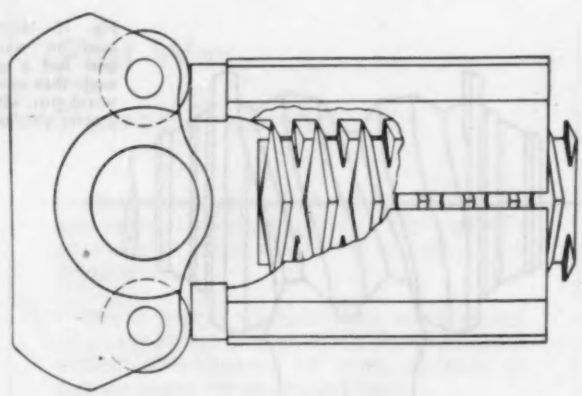


Fig. 7—Ross cam-and-lever gear, introduced in 1923, was the first of its kind and still found on some cars. It featured compactness, and a degree of reversibility much needed with the coming of better roads and higher speeds.

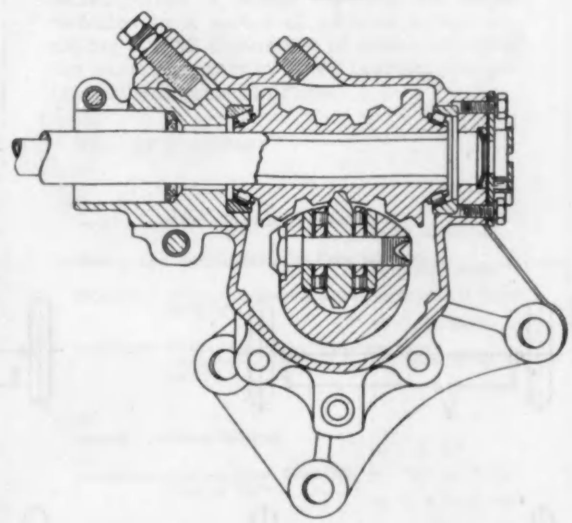


Fig. 8—Marles single-roller gear replaced sliding contact with rolling contact to create the first antifriction gear.

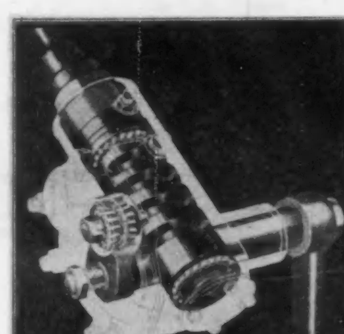


Fig. 9—Roller-bearing pin was added by Ross to cam-and-lever gear to make it an antifriction type.

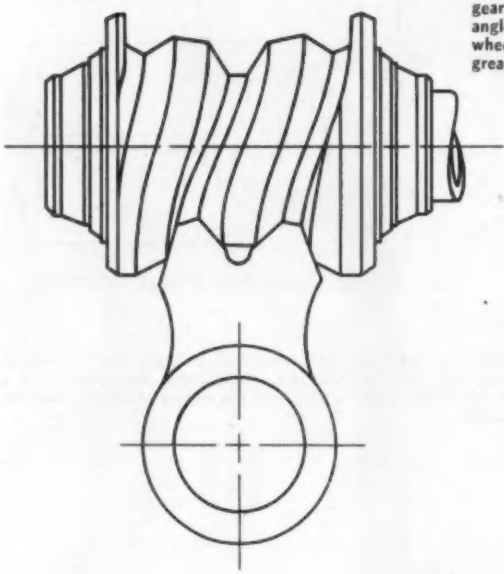


Fig. 10—Hour-glass worm used in worm-and-sector gear had a greater helix-angle than worm and worm-wheel gear, with consequent greater efficiency.

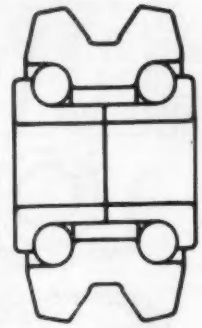


Fig. 11—Ball-bearing roller in Marles gear represented a big step forward in the march toward anti-friction type gears.

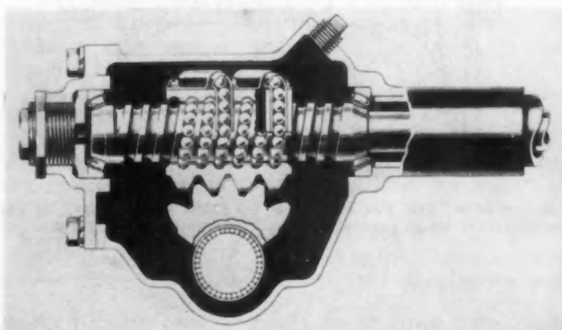


Fig. 12—Saginaw "circulating-ball" steering gear, introduced as World War II broke out, is basically a screw-and-nut type gear with addition of antifriction balls between the thread grooves of the screw and nut.

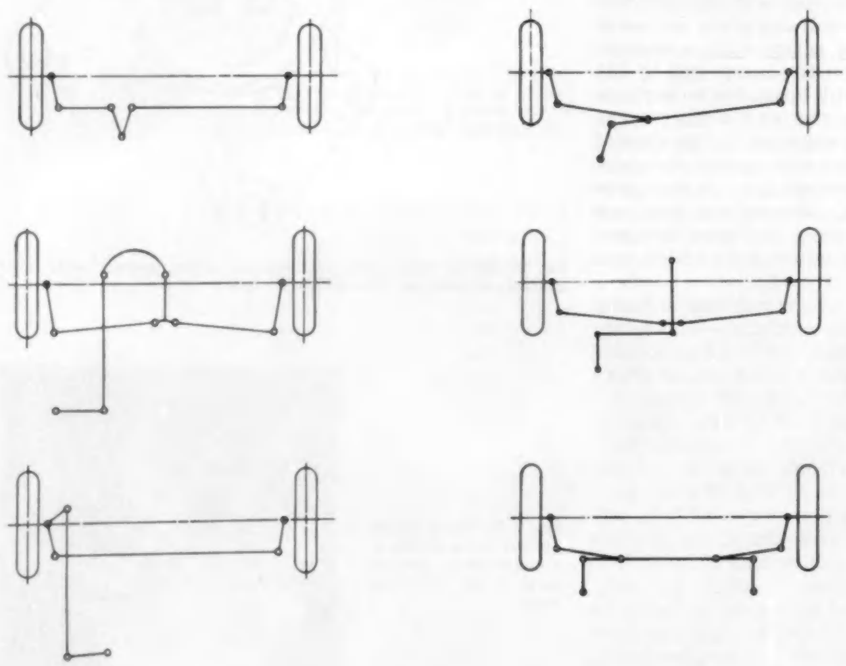


Fig. 13—These six typical linkages all represent modifications of the Jeantaud linkage of horseless carriage days.

viving in American cars.

Modern manual steering really had its development in the period 1928 to 1936. Prior to that none of the gears could be regarded as of the antifriction type. At the beginning of this period Ross added roller bearings to the pin of the larger sizes of the cam-and-lever gear (see Fig. 9). Gemmer, anxious to increase the angular travel of the steering arm in the Marles gear, replaced the single roller-tooth with the two-tooth roller and even made some gears with three-tooth rollers. Saginaw brought out its first worm-and-sector gear in 1929 (see Fig. 10) and when Chevrolet switched to it in 1931, the old worm and worm-wheel type passed from the picture except for use on a few trucks and lesser vehicles.

In 1933, Saginaw introduced the first ball-bearing roller-tooth in a Marles gear (see Fig. 11) and the next year Ross increased the angular travel of the steering arm of the cam-and-lever gear by providing the cross-shaft with a forked or "twin" lever in place of the single lever. This had two pins, one of which entered the worm thread as the other was leaving it. Then, in 1936, this twin-lever gear was given roller bearing pins. By 1936 then, all three manufacturers were producing anti-friction gears, although simpler gears were still available and in use. This situation still prevails but the proportion of anti-friction gears in use has increased steadily.

Just before World War II put a stop to car manufacture, Saginaw introduced a "circulating-ball" type of gear (see Fig .12). It was a reversion to the screw-and-nut type, but had anti-friction balls between the thread grooves of the screw and the nut. A few such gears appeared in 1939 and in 1941 it was used on all Buicks, Cadillacs, and Chevrolet trucks and on a large proportion of GM trucks and coaches.

Although the War put a stop to development of the lighter gears for cars, it did further the development of power steering by way of the military vehicle. The War over, Saginaw resumed manufacture of circulating-ball gears, roller-tooth gears, and a few gears of the worm-and-sector type. Gemmer was supplying roller-tooth gears, while Ross was furnishing cam-and-lever gears. Then, in 1951 and 1952, the continuous struggle to keep steering effort down as car size and weight increased, culminated in hydraulic power steering.

While the big developments in steering have been in steering gears, certain changes have been made in front-end linkages. These were primarily to avoid excessive changes in camber or wheel direction during action of springs or front suspensions, and sometimes for clearance considerations. Chief among these linkages are the "center-lever" and "parallelogram" types (see Fig. 13). In the former linkage, the fore and aft link transmits motion to a lever at or near the car center which in turn transmits motion through separate tie-rods to the knuckles. In the "parallelogram" type, the pitman arm has a counterpart idler arm on the opposite side of the frame, and the outer ends of the two arms are connected by a cross-rod. Separate tie-rods transmit the motion from this cross-rod to the two steering knuckles.

(For complete paper on which this abridgment was based, write SAE Special Publications Department, 485 Lexington Avenue, New York 17, N. Y. Price: 35¢ to members, 60¢ to nonmembers.)

Post-War Power Steering . . .

All steering gears discussed in this article are manual steering gears . . . no power is provided to assist the driver in turning his front wheels.

World War II furthered the development of power steering in general, even though it stifled development of such steering in lighter gears for passenger cars.

In 1951 and 1952, the continuous struggle to hold down steering effort in the face of size and weight increases culminated in the offering of hydraulic power steering for passenger cars.

Since then, SAE Journal has followed the development of power steering for motor vehicles in a series of articles which includes a 1952 discussion of power steering for passenger cars by C. W. Lincoln, the author of this present article.

The list includes:

1952

April —**Power Steering in 1952** by W. K. Creson

June —**Power Steering for Passenger Cars** by C. W. Lincoln

November—**History, Development and Application of Power Steering** by F. W. Davis

November—**Power Steering for Passenger Cars (Secretary's report of Round Table by W. A. Hunter)**

1953

January —**Power Steering** by F. M. Isor

November—**Linkage-Type Gears Vie for Slice of Power-Steering Plum** by W. A. McConnell

1954

January —**Power Steering Cracks Truck-Payload Barrier** by S. C. Johnson

February —**Power Steering Should Epitomize Doing What Comes Naturally** by T. H. Thomas

November—**True Center Point Steering** by A. S. Page

1955

February —**Power Steering Pot Still Boils Verbally** by R. A. Carrison

1956

February —**Power Steering Trends Hint Ultimate Design** by W. K. Creson

November—**The How and Why of Chrysler Coaxial Power Steering** by O. D. Dillman

2 Tooling Trends:

•Design of new tools, using new materials

•Redesign of old tools to do a better job faster and more economically

Here's some information on these trends as they apply to various types of tooling.

J. R. Cooke, Eclipse-Pioneer Division, Bendix Aviation Corp.

Based on the secretary's report of the panel on "New Trends in Tooling" held at the SAE National Aeronautic Meeting and Production Forum, New York, April 9, 1956.

Ceramic Tooling

CERAMIC tooling in production work is a new trend . . . which has led many tool designers to experiment with this "harder-than-carbide" material. The experiments have verified the reported qualities of ceramic turning so, a number of firms are using the more rapid speeds permitted by ceramics to acquire quality finishes low in the micro scale. These improved speeds mean improved finishes, another practical consideration in economic production.

Ceramics eliminate the cost of coolants, for they absorb little heat (the heat, being generated by the metal deformation, is carried away in the chip). And, aluminum oxide, the basic material of which ceramic tooling is composed, is abundant. Therefore, mass produced, refined ceramics are relatively inexpensive. These advantages are the forces leading tool manufacturers and tool users into further experimentation and refinement of ceramics.

Unfortunately, the advantages of ceramics are seriously affected by their brittleness. Because of it ceramics cannot be successfully applied to interrupted-cut operations. Some laboratories are experimenting with metallic bonds for ceramics to offset the "glass" bond's brittleness, but as yet have not marketed a "cured" product.

Magnesium Tooling

Air frame manufacturers are finding more and more applications for magnesium tooling. Favorable properties which have accelerated use of magnesium include:

- It is very light, (about 20% lighter than aluminum),
- It is machineable,
- It has good wear qualities, and
- Its thermostability is approximately the same as aluminum.

One danger of magnesium is the fire hazard that is present when machining. This danger can be avoided, however, by maintaining a high level of housekeeping, and by providing adequate fire-smothering substances, such as soapstone. The additional precaution of sharp tools with ample rake and small radii will also help to prevent flaming.

Disintegration Machining

Two methods of disintegration machining are in use today—the ultrasonic and the electrical discharge. The ultrasonic method produces the better finish, but the electrical discharge method permits a high rate of stock removal.

THE ULTRASONIC METHOD uses small cutting

particles which pound the material away. There is no tool contact in ultrasonic machining. The method, however, is particularly efficient for cutting hard materials and materials which have been historically impossible to machine, such as glass.

Most current ultrasonic applications are of a highly specialized nature, such as the production of carbide dies. Soft or ductile materials cannot be ultrasonically machined.

Unlike the ultrasonic method, at times the ELECTRICAL DISCHARGE METHOD has partial tool contact. In fact, the tool wear is sometimes equal to the wear factor of the work.

The finish produced by electronic discharge machining is a poor "eye" finish, which appears pitted, but actually the finish is far superior to a ground finish and the process will produce a longer wearing tool cutting edge than a diamond honed tool. (The heat generated by a diamond wheel creates incipient cracks which appear during the work cycle and cause tool wear.)

The electrical discharge method permits cuts to an accuracy of 0.0005 to 0.001 in. In a rapid cut, such as a ¼ in. hole through ⅛ in. carbide, 0.002 in. is the approximate maximum accuracy available. Here too, the use of the equipment is highly specialized.

Plastic Tooling

Where usable, plastic tooling yields savings of 30 to 70% over other common tooling forms. This economically intriguing statement is limited somewhat, however, by the "where usable" condition.

Plastics permit large local repairs. No special machine tools are required in the tool shop for the creation or repair of plastic tools. However, costly curing ovens are required. In addition, the abrasive quality of plastics makes their machining rather costly.

Plastic material is relatively indestructible, a desirable feature when extensive tool handling is needed. In such applications as drill jig design, bushings can be changed easily by the use of a quick-setting thermoplastic compound.

Shrinkage, air bubbles, and other technical disadvantages of plastic usage are usually solved in the individual applications and present no major problem, but one outstanding fault of the material does exist, namely the physical irritation which results from processing and machining plastics. Dermatitis . . . infection of the skin . . . causes considerable pain and discomfort. At present, good ventilation seems to be the main preventive control.

Modular Fixturing

The future of modular fixturing is as much a matter of promotion as it is of design, for the basic concept of modular fixturing is difficult to instill in today's "traditionally-trained" tool engineer. Modular fixturing, the creation of fixtures from basic structures, presents the ultimate in standardization and interchangeability. Modular fixturing makes the concept of "one tool for every job" practical. Its revolutionary nature, however, will require a retraining of the tool engineer and the toolmaker.

The use of modular fixturing today is limited to the visionary faculties of the designer, and the ac-

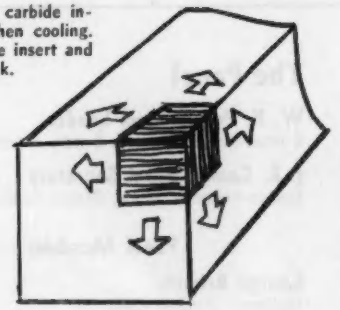


Fig. 1—Steel "pulls" on a carbide insert in many directions when cooling. This sets up stresses in the insert and frequently causes it to crack.

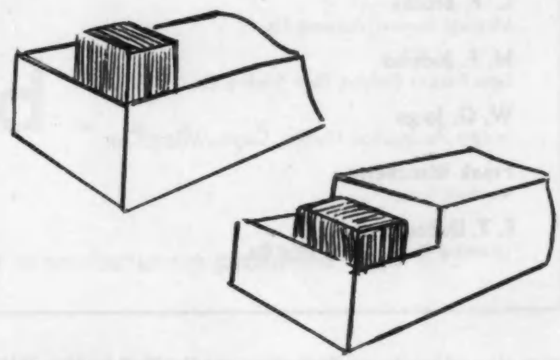


Fig. 2—By brazing the insert so that it has only one area of contact, stresses in the insert are avoided.

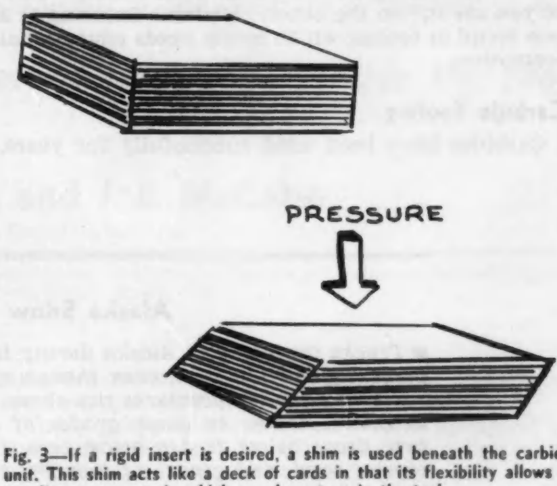


Fig. 3—If a rigid insert is desired, a shim is used beneath the carbide unit. This shim acts like a deck of cards in that its flexibility allows it to adjust to any strain which may be set up in the tool.

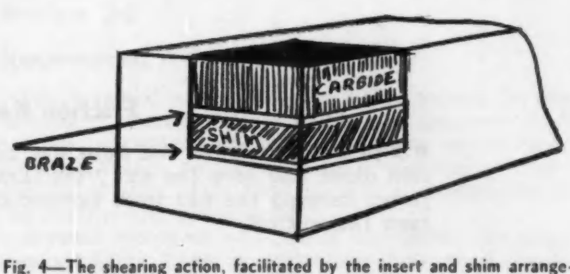


Fig. 4—The shearing action, facilitated by the insert and shim arrangement, permits stresses to act without damage upon the carbide insert.

The Panel

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curacies of modular fixturing are limited to the skill of the toolmaker-assembler.

Practical tool engineers acclaim the concepts of modular fixturing on one hand, while asking, "How do you use it," on the other. Modular fixturing is a new trend in tooling which sorely needs educational promotion.

Carbide Tooling

Carbides have been used successfully for years, but practical users have experienced some difficulty in brazing carbide inserts to steel shanks. A problem frequently arises in the nature of cracked carbide inserts . . . its causes may be simply defined as the stress resultant from unequal metal distortion.

In brazing at high temperatures the carbide insert is not distended as greatly as is the steel shank, and during the subsequent cooling, stress develops as the steel "pulls" on the insert. A cracked insert is frequently the result. Fig. 1 shows the directions of "pull" which occur during cooling.

There are several suitable methods of avoiding this problem. The simplest is to position and braze the insert so that there is only one area of contact, and consequently, only stress in one direction. This may be achieved by positioning the insert as in either of the methods shown in Fig. 2.

Since stresses in two directions are required to create a strain on the insert, these suggested methods will solve the cracking problem. If, however, the rigidity of the insert is of paramount importance, another method may be used. The insert is positioned with a shim, brazed in layers, so that the resulting insert will have freedom to adjust to the strain, much like a deck of cards can be distorted under pressure to change its shape from a rectangular parallelepiped to an oblique parallelepiped. See Fig. 3.

The shearing action, facilitated by the insert and shim, permits stresses to act without damage upon the carbide insert. Fig. 4 shows the design of the shimmed insert.

(The report on which this article is based is available in full, together with reports of 5 other panel sessions of the SAE National Aeronautic Meeting and Production Forum held in New York, April 9, 1956. This publication, SP-315, is available from the SAE Special Publications Department, 485 Lexington Ave., New York 17, N. Y. Price: $1.50 to members; $3.00 to nonmembers.)

Alaska Snow Acts Like Sand

■ *Trucks operating in Alaska during the winter require tire chains only a small percentage of the time, even though operating in snow most of the time.*

When the temperatures rise above 20 deg below zero, it is usually necessary to install chains to climb grades of any consequence. When the temperature drops below 20 deg below zero, snow on the road surface is similar to fine crystal sand, and grades of 8 or 9% can be negotiated without difficulty. The lower the temperature the more traction seems to be available and, in many cases, loaded vehicles can be started up severe grades without "chaining up."

—R. C. Norrie and R. H. Kasper

Friction Keeps Nuts On

■ *A properly designed and tightened bolted joint needs no locking devices. Friction alone will keep the nut from turning off the bolt. In fact, the frictional forces keeping the nut from turning are 6 to 9 times the forces attempting to turn the nut off.*

—E. J. Eckert

Getting Titanium Parts Mass Produced . .

. . . for turbojet engines presents four major manufacturing problems:

1. **Getting acceptable forgings;**
2. **Recovering adequate ductility in forgings by heat treatment;**
3. **Developing machining processes to produce titanium components successfully; and,**
4. **Reducing hydrogen content to acceptable levels in semi-finished or finished parts.**

Here's how one manufacturer solved these problems in the production of compressor discs.

J. L. LaMarca and J. L. McCabe

Aircraft Gas Turbine Division, General Electric Co.

Based on paper "Problems Related to the Introduction of Titanium into Production Turbojet Engines" presented at SAE Annual Meeting, Detroit, January, 1956.

Problem #1

Getting Acceptable Forgings

Early experience with titanium alloy forgings indicated that billet acceptance tests, based on forged pancakes rather than contour forgings, were not completely reliable. Some billets, predicted to produce forgings of unacceptable ductility, actually produced forgings of superior ductility, and vice versa.

Mechanical properties and metallurgical changes to be expected in service, such as overaging, were also found to differ between specimens taken from actual forgings and those made from bar stock.

Solving the Problem

As experience progressed, contour forgings of compressor rotor discs with superior ductility were made. Also, the use of vacuum-melted billets or those from low-hydrogen processes improved ductility.

Today progress and knowledge have advanced to the point where quotations are made on a firm price for the delivery of acceptable forgings, and where rejections are no higher than for steel forgings.

Problem #2

Recovering Adequate Ductility

While initial experience was being gained in the forging of titanium alloys, it became apparent that a large percentage of the forged discs would have ductility values, as reflected by elongation and reduction of area, below that considered acceptable to the engineering specifications.

Several hundred potentially rejectable forgings were set aside. Then we undertook the task of developing heat treatments to convert low ductility forg-

ings to those having acceptable values of elongation and reduction of area. A systematic program of exploration was evolved and promising heat treatments were followed up by stability tests to simulate engine operating stresses and temperatures.

Solving the Problem

The heat-treatment finally approved for production use on rough forgings is composed of a descending series of isothermal plateaus. Initial heating is somewhat above complete transformation temperature to give a thorough solution heat-treatment. Reprecipitations of coarse alpha are accomplished by holding for several hours in the isothermal region. Stabilization against age embrittlement is achieved by holding at 1200 F for 24 hr. The length of the cycle permits diffusion of metal atoms and interstitial elements.

During the heat-treatment of the rough forgings simple fixtures are used to minimize warping and to maintain flatness of the discs. The entire cycle is performed in one furnace where cooling rates can be controlled.

At the present time, all billets are of the vacuum-melted, low-hydrogen type, and the production forging techniques have been so improved that the need for restoration of ductility in forgings has practically disappeared.

Problem #3

Developing Machining Processes

While engineers and metallurgists were expending their effort on material problems, manufacturing personnel were combating the problems of machining titanium alloy. They were involved with such problems as surface finishes and distortion of compressor discs during machining.

Of course we were adding to the problems of our manufacturing personnel since we were beating this material to death in forging hammers and presses; also because the reheat treatment of the rough and, in some cases, the semi-finished disc forgings created residual stresses and increased the distortion of the discs.

The first major machining problem encountered was our inability to maintain a consistent microinch finish during the finishing cuts. Although a complete laboratory examination of the material was made of both acceptable and unacceptable discs, no raw material difference could be found which affected the finishes not acceptable to the engineering specification.

A parallel program of cutting tool design was initiated, and here we found our answer by making changes to the tool geometry.

Solving the Problem

Due to the complex shapes of the compressor wheel discs, such as conical contours, projecting lips and bosses, and many different radii, it was determined that a smaller radius, reduced from 0.060 to 0.030 in. on the nose of the cutting tool, helped. In addition, changing of the rake and clearance angles helped immeasurably.

Rake angles were increased from 10 to 15 deg. Unloading the tool, to remove chips quickly away from the workpiece, was necessary as we cut below the hardened crust of the forgings. This was accomplished by changing the primary and secondary clearance angles from 3 to 7.5 deg and 7 to 13 deg respectively.

These changes in tool design made it possible for us to get the consistent microfinishes required. But in doing so, the tool life became such that regrinding was necessary after cutting only 25% of the disc surface.

After many trials, cutting tool life was increased to the point where 100% of the disc surface could be finish-machined prior to regrinding of the cutting tools. This was accomplished by putting a better finish on the cutting tools by means of finer grit diamond grinding wheels.

In addition, wear lands of the tools were never allowed to exceed a width of 0.020 in. in order to maintain acceptably low cutting forces.

Distortion of discs during the final machining of the web area was the second major manufacturing barrier to hurdle. Normally, distortion may not exceed 0.010 in. measured from the rim area to any point on the disc face.

At first, we used our steel disc machining methods. Discs were located on the rim face and the inside diameter of the bore. Machine holding fixtures were used and discs were held down by mechanical clamps located around the rim and expanding mandrels at the inside diameter, both of which left the entire web surface unsupported. Due to the elasticity of this material the workpiece moved towards and away from the tool as it progressed across the work, causing excessive tool chatter, and distortion of the disc by as much as 0.25 in.

Movement of the disc had to be kept to a minimum, so, a series of concentric rows of hydraulic jacks were added to the fixture between the rim and bore supports in an attempt to support the web areas. These merely supported the workpiece in one direction, however, and still allowed it to move away from the hydraulic jacks.

To overcome this difficulty, the center row of hydraulic jacks was removed and replaced by a solid steel ring which acted as a seal. The area between this ring and the bore was evacuated so that the pressure difference across the area allowed the disc to set against the hydraulic jacks and effectively kept the workpiece from moving away from the jacks. This improvement aided in keeping distortion of the disc to a minimum including the localized distortions of the web area.

Problem #4

Reducing Hydrogen Content

Although we had successfully solved our raw material, forging, and manufacturing problems, we found that certain critical components of turbojet engines were susceptible to time-fracture failures. These failures occurred in titanium alloys containing more than 0.015% hydrogen.

Extensive investigations revealed that a combination of operating stresses and temperatures with hydrogen contents over 0.015% could result in failures, particularly in parts whose design incorporated notches or other stress concentrators. Decreasing

temperatures increase the detrimental effects of high hydrogen in developing brittle failures. And conversely, the influence of hydrogen in promoting brittle fractures decreases rapidly as the operating temperatures increase above 250 F.

Solving the Problem

As a result of the above investigations, it was decided to subject all parts in process, containing hydrogen above 0.015%, to vacuum annealing, and thereby reduce hydrogen content to acceptable levels. This was accomplished by heating the compressor discs in a vacuum retort for 24 hr at 1225 F and a vacuum level of one micron. This treatment reduced hydrogen content from a maximum of 0.035% to less than 0.0125%, with substantial increases in elongation and reduction of area.

Discs whose original ultimate and yield strengths were at or slightly below minimum specification requirements suffered further losses of these properties to a maximum of 8,000 psi.

Simple degassed fixtures made of low carbon steel were sufficient to maintain flatness of finished machined discs within 0.005 in. of the original dimensions. Even with the flatness problem solved, another unusual phenomenon was encountered. In vacuum-annealed finished discs, diametral shrinkage, in the order of 0.0005 in. per in. of radius, took place. This is chiefly due to a reduction in volume caused by the loss of hydrogen.

Some outside diameters failed to fall within the 0.001 in. tolerance required to insure adequate interference fits between mating surfaces. To salvage these discs, which otherwise would have gone to the scrap pile, we used the following method: using a form roller designed to fit the geometry of the protrusions on the disc, and using the vacuum chucks normally used in the finish machining operation, a steady uniform force is applied to the protrusions while the disc is rotated. Roller lubrication prevents galling. This cold rolling process increases the radius about 0.008 in., and subsequent machining restores the needed dimensions.

Destructive, nondestructive, and engine test evaluations substantiated our thinking that this process could be applied successfully to certain areas on the compressor disc.

(For complete paper on which this abridgment is based, write SAE Special Publications Department, 485 Lexington Ave., New York 17, N. Y. Price: 35¢ to members; 60¢ to nonmembers.)

Compressor Air Contamination . . .

. . . can be stopped. First choice is to use a catalytic filter. A separate compressor is more positive, but also more expensive.

Based on paper by **Henry A. Reddall,** North American Aviation, Inc.

INTERNAL engine oil leakage is the basic cause of contamination of air bled from the compressors of some high compression ratio turbojets, and the condition can be aggravated by external leakage of oils and other fluids which find their way into the engine air inlet. The contamination is not toxic but it is annoying enough to create a real problem, particularly in commercial airliners.

Obviously, every effort should be made to minimize or eliminate the leakage. If a major improvement can be made, then the air can be extracted from a location in the engine where there is least contamination. However, this is regarded as a marginal solution to the problem, perhaps satisfactory for military aircraft, but inadequate for commercial airliners where odorless air is a must.

There are two positive methods of elimination. One is to use a catalytic filter which oxidizes the contaminants into carbon dioxide and water; the other is to employ a separate compressor, using free stream ram air for cabin air conditioning and pressurization. Of the two, the latter is the more positive, but it is the heaviest, most complicated and most expensive way to arrive at a solution.

In the design of a filter, the selection of the filter media will depend on the temperature, pressure, and humidity of the air at the filter location. A schematic of a typical fighter aircraft air conditioning system is shown in Fig. 1. Locating the filter downstream of the air conditioning equipment raises serious problems with very few advantages. The probability of filter icing is very real. Volume flow and velocity of air through the filter is greatest at this point in the system because the system pressure is low. High velocity is undesirable for two reasons: it reduces the dwell time of the air passing through the filter, thus minimizing the effectiveness of the filter chemical compounds; it also produces high pressure drop across the filter with a resultant back pressure at the discharge of the refrigeration unit which reduces performance of this unit.

At the location between the refrigeration unit and the heat exchanger the air has a relatively narrow temperature range and is well worth consideration provided a suitable filter media can be found to work

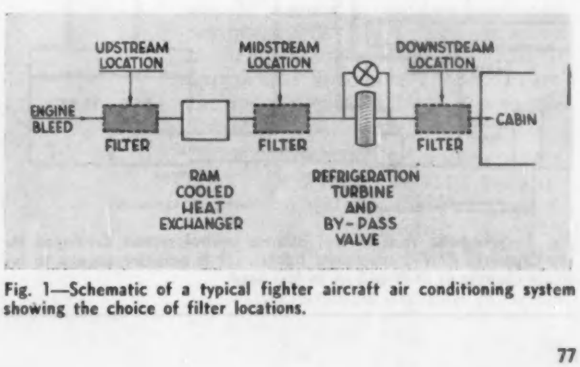


Fig. 1—Schematic of a typical fighter aircraft air conditioning system showing the choice of filter locations.

at these temperatures.

The upstream location with air temperatures up to 850 F presents problems making it unusable for other than high temperature particulate and catalytic filter materials. This location is free from icing problems, has relatively low volume flow due to high pressures, and is least sensitive to pressure losses. If a surface active combustion catalyst is used, the high temperatures are desirable from the standpoint of chemical reaction.

There are several factors to consider in designing a catalytic filter. These are the selection of filter media, dwell time, filter case, and filter pack.

The catalyst selection must be based on tests involving the contaminating material since many catalysts, capable of converting a variety of contaminants, may be ineffective with a particular contaminant.

Sufficient flow area and depth of the catalyst must be used in the filter pack so that the air velocity through the pack will be slow enough to allow the catalyst to purify completely.

The filter case must be designed carefully for stresses produced by the air temperatures and pressures. If the filter is located in the engine compressor bleed duct, it is necessary to have a round case with spherical ends, otherwise adequate stiffening will impose a weight penalty.

Catalysts of the solid type usually must be of a granular form in order to provide a maximum surface area for the air to contact. The granules must be firmly packed, though not crushed, to reduce attrition losses caused by vibration and to prevent the air velocity from separating the granules and forming a free path through the media. (Paper "Elimination of Engine Bleed Air Contamination" was presented at SAE National Aeronautic Meeting, October, 1955.)

New Fuel Balance System . . .

. . . developed for Grumman F11F-1 establishes close control of center of gravity travel.

Based on paper by **John Karanik,** Grumman Aircraft Engineering Corp.

THE Grumman F11F-1 supersonic fighter can stand no more than a 2% shift of the mean aerodynamic chord due to fuel usage if it is to stay within recommended flight center of gravity limits. This is in sharp contrast to an acceptable C. G. shift of 7% on a previous model, and a 9 to 13% on subsonic aircraft.

To exercise the necessary close control of C. G. travel, Grumman has developed a light weight, automatic, fuel balance system which regulates head between forward and aft fuel tanks and is independent of electrical power.

The system is shown in Fig. 1. It comprises four ¼-in. diameter sensing lines, a head control valve, pressure regulator and its lines, and a fuel transfer modulating valve. The cost of this system in weight is 11 lb.

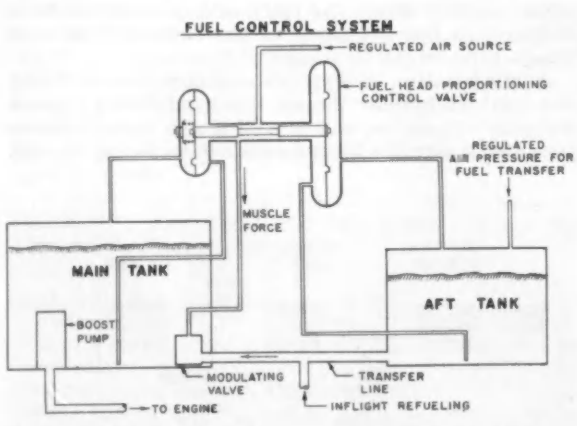


Fig. 1—Schematic view of fuel balance control system developed for the Grumman F11F-1 supersonic fighter. It is sensitive enough to indicate changes as little as 2 in. in fuel head.

A twin-diaphragm head control valve produces a varying head difference between the forward and aft tanks. The pressure due to the head of fuel applied to a diaphragm gives a working force. A pressure sensing line runs from the top of each tank to the control unit, making possible a canceling out of the effect of tank pressure on the respective diaphragms since it acts on both sides of the diaphragm. The head signal therefore is a true value of fuel head alone.

True head signals for the normal flight attitudes of the airplane are obtained by locating the head sensing points in the tanks as close as possible to the bottom of the mean fuel centroid. Errors could be introduced with an airplane attitude change if the sensing lines were filled with fuel. To obviate this an orifice is installed at the sensing point and a small purging air bleed is provided through these sensing lines during the system operation. The airbleed keeps the lines clear and the meniscus formed at the sensing point is, in effect, a pressure sensitive diaphragm which gives true head. The servo valve in the head control unit directs a muscle force to a modulating valve to control the transfer of fuel.

Continuing effort is being made to improve and refine system components. A recent design development has been initiated to provide a two-phase control schedule. At a desired point in total fuel usage, the control valve will shift to a new schedule, producing a different ratio of fuel usage between tanks. (Paper "Fuel Balance System for Supersonic Airplanes" was presented at SAE National Aeronautic Meeting, Los Angeles, October 1956. It is available in full, in multilith form, from SAE Special Publications Department, 485 Lexington Ave., New York 17, N. Y. Price: 35¢ to members, 60¢ to nonmembers.)

Tulsa Meeting Debates Current F&L Problems

A REGISTERED attendance of 525 made the 1956 National Fuels and Lubricants Meeting the largest ever held in Tulsa.

Predicted during the meeting was a new level for multi-purpose gear oil . . . perhaps soon. "All signs indicate that when we meet next year, tests defining a new level of activity will have been agreed upon . . . and the confusion surrounding gear lubrication will be no greater than that which, to a casual observer, seems to surround all human activity."

The hopes for alleviating these confusions, along with like problems in transmission lubricants and current engine-fuel relationships, were based on a currently increasing cooperation between motor vehicle and petroleum engineers. One petroleum engineer dramatized this growing willingness to work ahead together by naming a long list of vehicle men whose recent interest he felt had been outstanding.

The technical sessions, in fact, were replete with the fruits of forward thinking on problems of mutual petroleum-vehicle engineering concern.

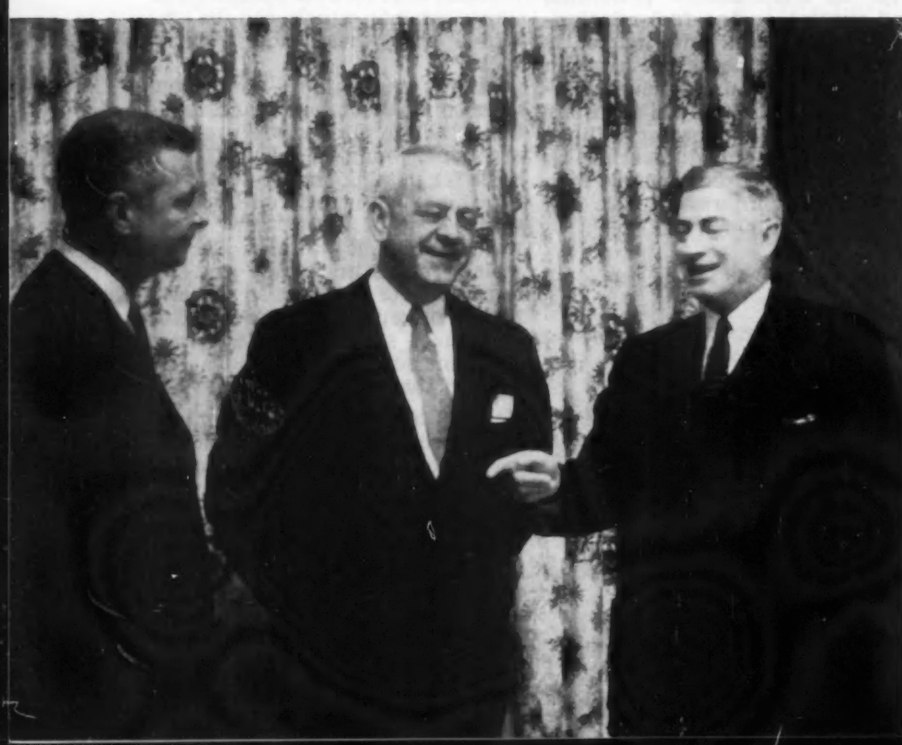
Several speakers, for example, brought out the fact that the modern V-8 engine requires a longer warmup period than did its in-line predecessors. One petroleum researcher, who concluded that V-8 warmup is no better nor worse than on previous in-line jobs, says this proves that warmup was and is no problem. "The car manufacturer," he argued, "has felt safe to trade warmup performance, due to improved fuels, for other engine improvements which can be obtained with these more volatile fuels."

Among new ideas presented were some about knock and antiknock action which, the presenters hope, "may be helpful as a basis for putting engine-fuel relationships on a rational foundation." One of these "new" ideas was that engine design factors which result in higher end-gas temperatures must also involve higher pressures, if engines are to appreciate sensitive fuels. From the same series of tests it was indicated that:

- "Chemical" octane numbers are directly related to ignition-delay characteristics. The relationship is such that a unit change in octane number means a constant percentage change in igni-

MID-CONTINENT SECTION members who handled arrangements for social events, publicity, registration, and ticket sales were (from left) **M. L. Alspaugh,** Mid-Continent Section Chairman **L. A. McReynolds,** General Chairman **W. F. Ford, H. M. Carey, W. W. Schafer,** and **J. L. McGinnis.** Also on the committee was **J. V. Brazier** who handled the housing of those attending the convention.

ON THE DINNER PROGRAM were speaker **Chester A. Lauck, M. D. Gjerde,** Toastmaster, and **SAE President Delaney.** Humorist Lauck for many years played Lum in the radio team of Lum and Abner. Now executive assistant for Continental Oil Co., Lauck called the oil industry the most competitive business in the world.



tion delay. (This explains why octane numbers become "larger" as they approach 100.)

- "Mechanical" octane numbers can be explained in part on the basis of nonuniform temperature distribution in the end gas.
- Tetraethyllead (TEL) shows antiknock properties only when it is decomposed before the fuel autoignites; the amount of antiknock effectiveness is related to the amount of TEL decomposed.

Deposits induced by surface ignition are being studied with an eye to the future. It was agreed that surface ignition will become more serious as the severity of engine conditions is increased to gain greater efficiency. One point made from studies already concluded is that "conditions probably exist where heat transfer from combustion-chamber gases can heat thermally-isolated deposit flakes to temperatures suf-

ficiently high to cause surface ignition."

Another new implication came from a new series of octane-needs-at-high-altitudes tests which were spread over very wide geographical areas.

"It would appear that there is no such thing as a basic altitude correction which applies to any given location," these researchers concluded. "Rather," they say, "it is necessary to have definite knowledge of the specific area under consideration—and of the driving habits of the people—and then be guided accordingly in making any adjustments to the standard correction which have been used in the past."

Another group exposed new results from road and laboratory vapor lock tests which, in general, confirmed that "the slope of the isovapor-lock line relating trace vapor lock to RVP and ASTM distillation varies directly with the car tolerance and ambient temperature."

Many research results revealed at the meeting added confirmation to previously known data.

One researcher, for example, concluded that "different engines or the same engine running under various test conditions will rate oils in different consumption ratios" . . . and "engine condition and operating characteristics may have a far greater influence on oil consumption than does oil viscosity grade."

In one case, chief interest centered in the relation between a new test procedure and the answers it produced about engine bearing wear. Set forth as a proposed new way to measure connecting rod bearing wear, the described procedure uses a radioactive tracer technique to measure bearing wear as it occurs.

Engine tests using the radioactive tracer wear technique produced observable differences in wear which agreed with previously calculated differences assuming the same test conditions. Calculations and tracer-techniques, in other words, agreed on such things as:

"A considerably higher rate of wear occurs under low engine load—high speed conditions than under high engine load—low speed conditions for given values of maximum bearing load." . . . and "Bearing wear is a function of

FUELS AND LUBRICANTS ACTIVITY Vice-President **Leonard Raymond** (left) and Meetings Vice-Chairman **C. J. Livingstone,** who guided development of the technical program for the successful meeting.

Around the F & L Meeting . . .

More than 200 of the 525 engineers at Tulsa registered a day in advance of the official opening of the meeting. . . . **W. F. FORD,** general chairman of the meeting, sparkplugged the idea of making registration facilities available in advance. Nearly 100 of these early arrivals attended a special performance of old-time melodrama given by The Spotlight Club on the evening preceding the meeting's start.

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Attendance at the technical sessions—as well as total registrations for the Meeting—broke records . . . and the Thursday Dinner and the Friday Luncheon were outstanding events, too.

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LEO A. McREYNOLDS, Mid-Continent Section chairman, welcomed the members to Tulsa as he opened the meeting officially before the Thursday morning session. He spoke on behalf of the following Sections in addition to his own: Texas, South Texas, Texas Gulf Coast, Wichita, and Kansas City.

Around the F&L Meeting . . .

U.S. customers driving 60,000,000 cars with conventional engines will expect today's fuels to remain available for many years to come. In a "Meet the Press" interview held during the SAE National Fuels and Lubricants Meeting in Tulsa, automobile and fuel research engineers made it clear that no quick changeover in automobile fuels and engines is anticipated.

None of those interviewed could be pinned down to predicting whether future cars will be powered by turbines, free piston, or atomic engines. Said **Lloyd Withrow** of General Motors Research "We do not predict how our results will come out. Our laboratory tests tell us which way to move."

Interviewed were:
(Left to right) **E. J. McLaughlin,** California Research; **F. C. Burk,** Atlantic Refining; **Lloyd Withrow,** General Motors Research; **R. I. Potter,** Ford Motor; **Charles Heinen,** Chrysler; **J. J. Mikita,** Du Pont; and **Leonard Raymond,** Socony-Mobil Oil. **Mikita** served as moderator at the interview during which five reporters quizzed the engineers on new developments in engines and fuels. Arrangements for the lively "Meet the Press" conference were made by **D. W. Frison.**

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Research continues on new forms of power with the two industries exchanging information from the initiation of a project. The automobile manufacturer provides experimental engines and the oil producer researches for the required fuel.

At the Thursday press conference **E. J. McLaughlin** of California Research forecast that with new engines the greatest problem would be one of distribution rather than availability of the necessary fuels.

At the dinner on Thursday evening **SAE President Delaney** called this exchange of information between the petroleum and automotive industries the perfect example of cooperative effort, emphasizing that neither could exist without the other.

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Real problems are current in the application of the new automatic transmission fluids, off-the-floor discussions revealed. F&L Activity Committee, in fact, has about concluded that an airing of the problem in round-table discussion is due . . . and aims to get something set up for Summer Meeting exposure.

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1956 Indianapolis winning car is being shown by **Jack Zink,** its builder, (left) to General Chairman **W. F. Ford** and **J. V. Brazier** (right). Introduced by Brazier at the Friday luncheon, Zink presented a colored film of the Indianapolis race and answered questions regarding the 500-mile race.

both the magnitude and source of maximum bearing load."

Eleven technical papers were presented at the four technical sessions which made up the two-day meeting. Scheduled to return to Tulsa in 1958, the 1957 SAE National Fuels and Lubricants Meeting will be in Cleveland . . . at the Hotel Statler . . . from November 6 to November 8.

Session Chairmen were: L. A. McReynolds, Phillips Petroleum Co.; **J. A. Edgar,** Shell Oil Co.; **E. J. McLaughlin,** California Research Corp.; and **N. A. Hunstad,** Research Staff, General Motors Corp.

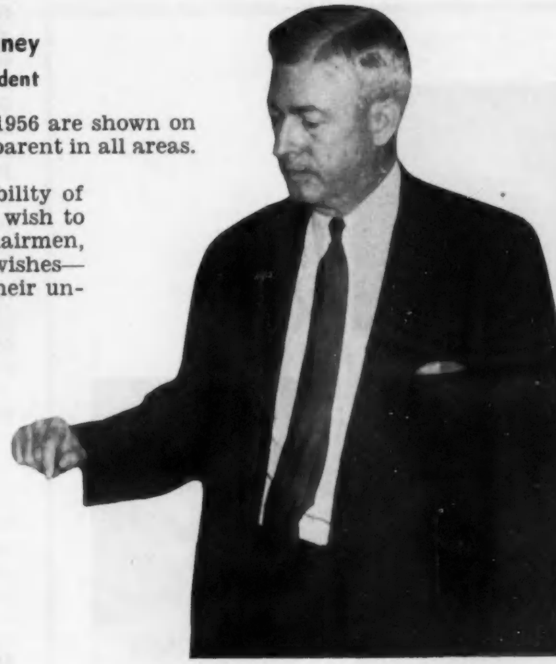
Session Secretaries were: H. M. Trimble, Phillips Petroleum Co.; **B. W. DeLong,** Shell Oil Co.; **M. W. Savage,** California Research Corp.; and **R. F. Gasvoda,** Ford Motor Co.

Papers presented at the SAE National Fuels and Lubricants Meeting in Tulsa, Oklahoma, on November 8–9, 1956, were: "Effect of Fuel Volatility on Starting and Warm-Up of New Automobiles," by **G. T. Moore, R. D. Young,** Standard Oil Co. (Ind.), and **H. A. Toulmin,** Ethyl Corp.; "A Study of the Cold-Starting and Warm-Up Performance of Some Recent Model Cars," by **W. P. Dugan,** Sun Oil Co.; "Weather or Lock, Vapor Lock Study, Road and Laboratory," by **D. P. Barnard V, R. B. Fell, E. H. Scott,** Standard Oil Co. (Ohio), and **Gilbert Way,** Ethyl Corp.

"Some Factors Affecting Engine Oil Consumption," by **H. V. Lowther,** Socony Mobil Oil Co., Inc.; "Effect of Oil Volatility and Additives on Engine Octane Requirement," by **F. S. Wood** and **C. C. Colyer,** Standard Oil Co. (Ind.); "Radioactive Tracer Measurements of Engine Bearing Wear," by **M. W. Savage** and **L. O. Bowman,** California Research Corp.; "A Basis for Understanding Antiknock Action," by **E. B. Rifkin** and **Cleveland Walcutt, Jr.,** Ethyl Corp.

"The Octane Requirement of Passenger Cars at High Altitudes," by **P. L. Haines** and **A. E. Brenneman,** Esso Research and Engineering Co.; "Some Factors Involved in Surface Ignition in Spark Ignition Engines," by **D. B. Wimmer,** Phillips Petroleum Co.; "Performance Testing of Gear Lubricants in Military Equipment," by **R. E. Streets,** Department of the Army; "New Developments in Gear Lubricants," by **C. M. Heinen,** Chrysler Corp.

An Evaluation of SAE by George A. Delaney
1956 SAE President



THE highlights of our Society's activities during 1956 are shown on the following pages. Encouraging progress is apparent in all areas.

This progress is a tribute to the energy and ability of the many committees which direct our affairs. I wish to thank each of them for a job well done. Their chairmen, their members and the staff who carry out their wishes—all have earned the gratitude of the Society by their untiring work and wise counsel.

Although I have been a member of the SAE for over thirty years and have actively engaged in its work during most of that time, it has taken this year as president for me to grasp the true size and scope of this great Society. The physical problem alone of constructing eleven national meetings points up the magnitude of only one phase of our operations. And there are a dozen others which call for equal effort and ability.

I have been particularly impressed with the high caliber of all our operations—in meetings, in the Sections, in our technical committees, in publications, and in our administrative committees. It is a truly heartening experience to find in each of these areas a group of members who enthusiastically devote so much of their time and talents to SAE.

To serve as your President has been a memorable experience. To each and all of you who have done so much to make it so, I extend my sincere thanks.

Planning and Progress in 1956

QUANTITATIVE progress has been made again in 1956 in membership, number of people attending meetings, student enrollment, amount of technical information published . . . and in the size of the Society's reserves.

Council moved the headquarters offices on October 8 to expanded quarters adequate to the continued growth and projected needs of the years ahead.

Measurable progress was made also along lines which do not lend themselves to numerical evaluation. Chief among these most important advances was the practical start made in planning for progress.

Activated in January, 1956, a Planning for Progress Committee is examining the Society's present structure in relation to obviously increasing needs. These needs, the Committee feels, are for flexibility, for reasonable continuity in the work of the various committees, and for even greater participation on the part of more and more members. This Committee, inaugurated by the 1956 Council at the suggestion of President Delaney, will continue its well-begun work during 1957.

Activities Refine Work Methods

The Society's various Activity Committees have all taken some specific steps looking toward (a) better technical service to SAE members, and (b) specifying what information is wanted in advance of paper presentations. This latter step aims to insure an author's presentation of material definitely needed and wanted.

Some Activity groups have gone further than others; some are planning additional moves in 1957. Throughout, however, there is growing clarification of the basic aims of Activity Committees as being the development, collection and distribution of technical information.

New "Overseas" Project

Also aimed toward better technical services to members was establishment in 1956 of an advisor to the president on overseas activities. His aim: to explore the possibilities of getting more and fresher technical information from abroad into SAE meetings and SAE publications.

Nuclear Energy Interest Up

The exploration into possible SAE interests in the nuclear energy field—started in 1955 with the late

E. K. Brown
Chairman
Constitution Committee

A. T. Colwell
Chairman
Finance Committee

E. S. MacPherson
Chairman
Meetings Committee

R. S. Frank
Chairman
Membership Committee

Herbert Happersberg
Chairman
Placement Committee

A. L. Pomeroy as an advisor to the president—took clear form in 1956 as a Committee. Its objectives too, are to help to get into SAE meetings and publications fresh and practical material of value to SAE members. So effective has been this work and so great has been the interest of many Activity Committees, that a special section of SAE Journal for February, 1957, is being devoted to nuclear energy data developed through these two facets of Society progress.

$$ for CEP

Financial support from industry for SAE's cooperative technical committee work reached a new high in the 1955–56 fiscal year. Industry furnished $228,260 to support the SAE Cooperative Engineering Program.

This past year brought forth two incentives to setting higher goals for the coming year.

1. Industry demand for increased cooperative activity within SAE technical committees.
2. A Council resolution that industry bear the entire cost of the Cooperative Engineering Program.

More Technical Information

Publications brought to SAE members a slightly greater volume of technical information in 1956 than in the previous year. Only SAE Journal, however, increased its actual number of copies distributed. In 1955–56, SAE Transactions was bought by 38.7% of SAE members, as against 49.0% in the previous year. SAE Handbook, carrying a $1-to-members charge for the first time, went to 54.8% of SAE members as opposed to the 75.1% who got free-on-request copies the previous year.

Publication Committee during the year set up specific methods for handling papers which win prizes in student contests sponsored by SAE Sections.

New Membership Action

Although "campaigns," as such, are not a part of the SAE membership picture, 1956 saw special programs launched to steer membership efforts in directions most conducive to quality membership growth.

The aims, activities and accomplishments of SAE are getting fresh showing to top-management executives, and an increasing number are being attracted to SAE membership. As key men become more cognizant of what SAE accomplishments mean to their companies, to their engineering employees and themselves, it is felt that they will be more understanding of the time and effort engineers devote to SAE.

Another project is to convey to non-SAE-members serving on technical committees the feeling that they are welcome as members of the Society, while at the same time assuring them that SAE membership is by no means a prerequisite to technical committee membership.

Society membership continues to grow. The fiscal year closed with 21,699 active members, a net increase of more than 1,000 over the close of the previous fiscal year; additions were 2,297 and losses 1,284.

Membership Grading Committee personnel has been increased from 15 to 21 to meet the increasing

volume of work demanded of this group. Continued heavy flow of applications for membership (which are listed monthly in SAE Journal) is one factor increasing the load. In addition there has been a decided increase in the number of members seeking reclassification, . . . particularly among Juniors who are reaching the age limit for that grade. Last year, acting upon Membership Grading Committee's recommendations, Council elected 989 candidates to Member grade, 480 to Associate grade and 974 to Junior grade. It also took action on 576 applications for transfer of grade.

Life membership may now be purchased by members over 60 years of age who have completed at least 20 years of active SAE membership. This revision in the Society's Life Membership Policy is the result of Council action taken at the recommendation of the Membership Committee Executive Committee.

New Requirements for New Sections

There now must be a minimum of 50 members in a local area with a potential of 100, with at least 60% holding Member and/or Junior grade of membership, before the Council will consider an application for the formation of a new SAE Group. Also, there must be at least 100 members with 60% holding Member and/or Junior grade of membership before a new Section may be authorized. This step-up in number of members and in ratio of technical members has been taken to assure greater strength in Sections and Groups with a continuing source of officer material and a sound basis for further growth.

Study of the best means to provide Section affiliation to interested members located outside of Section territory led the Council to reaffirm a previous action through which any member residing outside Section territory, upon written request for assignment to membership in a given Section, may be so assigned. The Council further provided that this information be brought to the attention of the membership each year by publication in the SAE Journal.

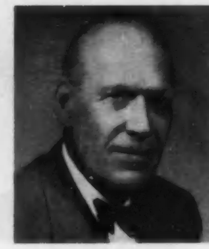
To provide greater continuity in the Sections Committee, and more particularly in the Sections Committee Executive Committee, Council amended the By-Laws to increase the number of members-at-large to be appointed by the President from three to five, and to increase the terms of their membership from three to five years.

The SAE South Texas Group, authorized during the year, increased the number of Groups to 5. The new group, a Division of the SAE Texas Gulf Coast Section for several years, demonstrated its ability to stand on its own feet. It had the Section's full support in its petition for Group status. SAE Sections continue to number 39.

New Technical Board Programs

The Technical Board and its committees achieved objectives in 1956 toward their goal of improving SAE services geared to industry's technical information needs.

Two new administrative programs undertaken by the Board in 1956 are aimed to amplify these services in 1957. These two programs are being implemented by a new Publication Policy Committee of the Technical Board and a new Technical Committee Guideposts Committee.



M. A. Thorne
Chairman
Public Relations Committee

T. L. Swansen
Chairman
Publication Committee

E. N. Cole
Chairman
Sections Committee

J. A. Bolt
Chairman
Student Committee

R. F. Kohr
Chairman
Technical Board

B. B. Bachman
Treasurer

1956 Financial Moves

The Finance Committee maintained during 1956 an equal distribution of the SAE investment dollar between U.S. Government bonds and stock equities; the former for safety of the dollar, the latter as a hedge against inflation.

As the year closed, the Committee was consulting its investment counselor on the advisability of seeking higher yield through the medium of convertible preferreds and corporate bonds. Continued is the philosophy of using income from securities and proceeds of bond maturities for further investment.

The objective of reserves equal to one year's expenditures remains inviolate. At cost value of securities, reserves stood at 65% of the goal; at market value 80%. Expenses were $1,610,000.

Once again the Society was so operated as to produce a black figure in excess of budget expectancy, but one-time moving expenses for headquarters kept to a minimum the net addition to reserves.

Financial statements at September 30 appear on following pages.

The Publication Policy Committee is seeking to establish policies and guidance for most effective distribution of technical reports developed by committees under the Technical Board. Such guidance will consist of:

1. Criteria to permit determination of the most feasible method of distribution in line with breadth of interest of each report and cost considerations.
2. Definition of report classifications so as to establish uniformity of classification by all committees.
3. Suggestions aimed at achieving greater uniformity and consistency of format and organization of reports.

The Technical Committee Guideposts Committee will develop for technical committees and their members a guide to sound operations. These guideposts will grow out of the Technical Board Rules and Regulations and currently successful committee practices and traditions, aimed at:

1. Bringing about a uniformity of understanding of Technical Board principles and philosophies, yet permitting a maximum of operating autonomy in each committee.
2. Preserving and extending satisfactions to engineers from their technical committee participation.

Technical Committee Services Grow

Among the scores of important projects completed by technical committees under Technical Board direction in 1956 were the following:

- The SAE Lighting Committee revised standards for Sealed Beam units to cover the new four-lamp headlighting systems now being used on some 1957 cars.
- The SAE Aircraft Hydraulic and Pneumatic Equipment Committee established temperature range classifications for both present and future equipment. This classification is receiving wide acceptance from engineers both in industry and in the military services.
- The SAE Transmission Committee completed a report which establishes a standard test code for passenger car automatic transmissions.
- A useful inspection tool was developed by the Iron and Steel Technical Committee. It's a General Information Report on Classification of Major Visible Imperfections in Sheet Steel.
- The Construction and Industrial Machinery Technical Committee continued to make technical contributions to the military services by completion of several test codes for the Corps of Engineers on earthmoving machines.
- A report of the Joint Subcommittee of the SAE Truck and Bus Technical Committee and the Riding Comfort Research Committee helped show the way toward designing better ride characteristics into trucks.

Among the significant new projects launched during the past year was the opening of the joint aeronautical-ground vehicle drafting standardization program. The aim of this program, as visualized by the Technical Board, is to replace the two separate SAE aeronautical and ground vehicle drafting manuals with a single drafting manual.

In the field of automotive safety, 1956 furnished additional experience that will provide the basis for a comprehensive revision in the SAE Recommended Practice for Motor Vehicle Seat Belt Assemblies. The changes now under way will improve the recommended practice both from the standpoint of test procedure and requirements.

The SAE Engine Committee is in tune with new technical advances in motor vehicle engineering. An example is the advent of dry aircleaners. The Committee recently launched a program to develop a test code for these cleaners.

continued on page 90

ACCOUNTANTS' CERTIFICATE

Society of Automotive Engineers, Inc.:

We have examined the balance sheet of the Society of Automotive Engineers, Inc. as of September 30, 1956 and the related statement of income and expenses, and general reserve, for the year then ended. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

In our opinion, the accompanying balance sheet and statement of income and expenses, and general reserve, present fairly the financial position of the Society at September 30, 1956 and the results of its operations for the year then ended, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

New York, November 23, 1956

Haskins & Sells

BALANCE SHEET

September 30, 1956 — ***In Agreement with Haskins & Sells Audit***

ASSETS		LIABILITIES & RESERVES	
General Cash	**$ 295,259.41**	**Taxes and Accounts Payable**	**$ 57,892.37**
Restricted Funds:		**Section Dues Payable**	**26,098.00**
Cash	**14,192.06**		
Securities	**19,845.00**	**Deferred Credits to Income:**	
Notes and Accounts Receivable—Less Reserve	**17,668.60**	Members Dues Received in Advance	**221,913.85**
Investment Funds:		Journal Subscriptions	**8,913.14**
U. S. Government Bonds	**x 459,310.98**	Transactions and Handbook	**15,451.50**
Preferred and Common Stocks	**x 458,362.55**	Dinners and Displays	**39,968.25**
Cash for Reinvestment	**4,093.45**	Other	**3,886.40**
Accrued Interest on Bonds	**3,088.85**	**Reserves for Restricted Funds**	
Inventories	**48,808.99**	Memorial Funds	**14,192.06**
		Other—Received during year	**19,845.00**
Furniture and Fixtures—Arbitrary Value	**1,000.00**	**General Reserve**	**977,958.37**
Prepaid Expenses	**64,489.05**		
TOTAL	**$1,386,118.94**	**TOTAL**	**$1,386,118.94**

x Investments Carried at Cost. Market Quotation or Redemption Values at 9/30/56:

U. S. Government Bonds	***$ 433,232.50***
Preferred and Common Stocks	***731,510.31***
TOTAL	***$1,164,742.81***

INCOME AND

October 1, 1955, to September 30, 1956

INCOME

MEMBERSHIP		
Dues and Journal Subscriptions	$478,080.50	
Initiation Fees	35,894.00	
Emblem Sales	1,696.10	$ 515,670.60
PUBLICATIONS		
Journal and Transactions Sales	55,545.81	
Journal Advertising	519,761.75	
Handbook Sales	44,444.50	
Handbook Advertising	23,967.25	
Aeronautical Publications Sales	58,229.34	
Special Publications Sales	59,801.52	761,750.17
NATIONAL MEETINGS		
Registration Fees and Preprint Sales	23,296.97	
Dinners and Luncheons	50,679.80	
Displays	59,640.00	
Summer Meeting Registration Fees	10,680.00	144,296.77
SECURITIES		
Interest on U. S. Government Bonds	11,823.80	
Dividends on Stocks	18,401.01	30,224.81
CASH DISCOUNTS EARNED		1,822.67
TOTAL INCOME FOR MEMBER SERVICES		1,453,765.02
INCOME FOR TECHNICAL BOARD OPERATIONS		
Funds from Industry	228,259.85	
Transfers from Deferred Credit Account	4,064.80	232,324.65
TOTAL INCOME		$1,686,089.67

EXPENSE STATEMENT

In Agreement with Haskins & Sells Audit

EXPENSES

SECTIONS AND MEMBERSHIP		
Sections Department	$ 15,979.99	
Sections Dues and Appropriations	78,295.74	
Membership and Students Department	46,794.90	
Miscellaneous Membership Expense	1,389.33	$ 142,459.96
WESTERN BRANCH OFFICE		27,613.68
PUBLICATIONS		
Journal and Transactions Editorial	228,119.20	
Roster (13th Journal Issue)	36,754.44	
Journal Advertising	256,627.63	
Handbook Production and Mailing	82,884.88	
Handbook Advertising	9,035.12	
Aeronautical Publications	31,630.67	
Special Publications	34,318.52	679,370.46
NATIONAL MEETINGS		
Department Expense	58,223.58	
Registrations and Preprint Costs	10,470.39	
Meetings	55,522.90	
Dinners and Luncheons	48,410.02	
Displays	16,796.13	
Awards	1,084.84	190,507.86
ADMINISTRATIVE ***(See distribution on next page)***		
General Management	134,551.92	
Service Departments	135,898.98	
Furniture and Equipment	16,683.27	
Employee Benefits	51,727.21	
SAE Council and Committees	8,597.60	
Miscellaneous	7,129.49	354,588.47
TECHNICAL BOARD OPERATIONS		
Technical Committees	157,709.92	
Handbook Editorial Salaries & Expense	11,948.66	
CRC Appropriation	31,250.00	
Solicitation of Funds from Industry	14,489.74	215,398.32
TOTAL EXPENSES		$1,609,938.75
Excess of Income over Expenses Before Extraordinary Income (Deduction) shown below		76,150.92
Gain on Disposal of Securities		19,860.47
New Headquarters' Expenditures — Furnishings, equipment (in addition to $16,683.27 included under Administrative), leasehold improvements, moving expenses, etc.		(61,459.63)
Excess of Income over Expenses and Extraordinary Items		34,551.76
General Reserve at Beginning of Year		943,406.61
General Reserve at End of Year		$ 977,958.37

Distribution of Administrative Expenses to Other Divisions

To	%	Admin. Exp. Distributed	Direct Expenses	Total Expenses
Sections and Membership	11.3	$ 40,068.49	$ 142,459.96	$ 182,528.45
Western Branch Office	2.2	7,800.95	27,613.68	35,414.63
Publications	54.1	191,832.36	679,370.46	871,202.82
National Meetings	15.2	53,897.46	190,507.86	244,405.32
Technical Board Operations	17.2	60,989.21	215,398.32	276,387.53
TOTALS	100.0	$354,588.47	$1,255,350.28	$1,609,938.75

continued from page 86

Criteria for SAE Awards

The Recognitions and Awards Committee, during 1956, developed criteria by which it believes the Society might determine the acceptability of new proposals in this area. It satisfied itself as to the practicality of these criteria by making test applications to already existing situations. Thus, the Committee took what it considered the first necessary step toward completion of its mission to suggest to Council an integrated program of recognitions and awards for the Society.

More Enrolled Students

Engineering students taking advantage of SAE Student Enrollment increased by more than 17% last year, with 4,597 listed from 105 engineering school campuses. SAE has active Student Branches at 53 of these schools, and there are informal SAE Clubs at another 11.

Realizing that many engineering students enter the military service within the year following graduation, the Student Committee Executive Committee had encouraged graduating students uncertain of their draft status to file applications for membership at the time of graduation, with the understanding that adjustments will be made for those being called into service.

Local Publicity Continued

Publicity, developed for and at the cities where National Meetings are held, continued to comprise a major part of the work proceeding under policies of the Public Relations Committee.

More Jobs Than Ever

Job opportunities available to SAE members through the Society's Placement Service have reached a new high in 1956.

Approximately 1,000 copies of SAE Men Available are mailed twice monthly to an active company list. Almost all of these employers have taken advantage of the SAE Positions Available Bulletin to publicize their requirements.

Papers Quality and Presentation Bettered

Definite progress was made in 1956, through the leadership of our Meetings Committee, in improving both the quality of information presented at National Meetings and the efficiency of its communication. Particular emphasis was placed on strengthening three critical areas by:

1. Making sure that papers submitted by speakers are what the Activity Committees want —that they meet the written specifications approved by the Activity Committees.
2. Making sure that realistic session schedules that allow adequate time for extemporaneous discussion from the floor are developed and carried out.
3. Making sure that the technical information is communicated effectively—that everyone at a session with normal audio and visual faculties can hear the speaker distinctly and can clearly see the slides, motion pictures, and exhibits.

Participation of members and guests in National Meetings rose to a new high during the year. Total registration at SAE's eleven 1956 meetings was 16,497, 8% higher than in 1955.

More comprehensive engineering displays enhanced the value of the Annual, and New York and Los Angeles Meetings, and filled the growing needs of exhibitors for display booths. During 1956 the number of booths was increased from 212 to 229 and income from $53,885 to $66,215.

To develop a program for the SAE Annual Meeting Dinner that will coincide more closely with the needs and desires of members, a special Program Committee appointed by our Meetings Committee was initiated during 1956.

WHERE SAE FUNDS CAME FROM . . .

30.3%	MEMBERSHIP FEES AND DUES
44.7%	PUBLICATIONS SALES, INCLUDING ADVERTISING
8.5%	REGISTRATION FEES, DINNERS, AND DISPLAYS AT NATIONAL MEETINGS
2.9%	SECURITIES INCOME AND PROFITS
13.6%	CONTRIBUTIONS FOR TECHNICAL BOARD OPERATIONS

. . . AND HOW THEY WERE SPENT . . .

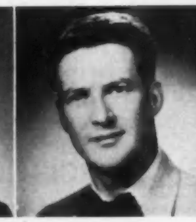
SECTIONS AND MEMBERSHIP EXPENSES	*x* 12.8%
PUBLICATIONS, INCLUDING ADVERTISING	*x* 51.1%
NATIONAL MEETINGS, DINNERS, AND DISPLAYS	*x* 14.4%
TECHNICAL BOARD OPERATIONS	*x* 16.2%
EXTRAORDINARY EXPENSES	3.6%
NET INCOME ADDED TO GENERAL RESERVE	1.9%

***x* Includes prorated administrative expenses**

About SAE Members


Barth


Trowbridge

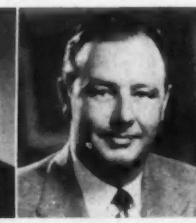

Harmon


Cullen


Colbert


Schwendler


Newton


Welker

J. L. S. SNEAD, JR., president of Consolidated Freightways, Inc., was elected chairman of the board of governors of the Regular Common Carrier Conference, a division of the American Trucking Associations, Inc.

E. B. OGDEN, formerly director of the progressive research and development program at Consolidated Freightways, Inc., has been made vice-president of equipment development at Consolidated Freightways. He will be concerned with the maintenance of technical progress of C-F's highway, office, and terminal equipment.

Ogden joined Consolidated 24 years ago as a mechanic in Portland, Ore.

EUGENE M. MITCHELL, who for 11 years has served Dayton Steel Foundry as special representative, has been made assistant sales manager at Dayton Steel. He will supervise sales contacts and head up a new program of market development.

REN C. McPHERSON, previously axle sales manager, Dana Corp., has been named manager, Auburn Division, Dana Corp. For three years prior to assuming the post of axle sales manager, McPherson was a sales engineer covering the major automobile manufacturers for Dana Corp.

WILLIAM L. BARTH has been transferred to special assignment on the staff of **CHARLES A. CHAYNE**, vice-president of engineering, General Motors Corp.

ROY P. TROWBRIDGE has been named to succeed Barth as director of GMC's Standards Section.

Barth has been responsible for administration and coordination of the very extensive standardization program carried on by GMC for many years. He has contributed outstandingly to SAE technical committee work through participation and leadership in many of the Society's most important technical committee projects, and as SAE's representative on ASA Sectional Committees.

Trowbridge has been assistant to Barth for a number of years.

R. A. HARMON has been appointed manager, district sales, Twin Disc Clutch Co., Racine, Wis. Previously, he was district sales supervisor for Twin Disc Clutch. Harmon joined the company eight years ago and has served as a field engineer, eastern district sales engineer, and manager of dealer sales.

O. E. CULLEN was guest speaker at the Chicago-Western Chapter of the American Society for Metals, where he spoke on "Modern Quenching Techniques." Cullen is chief metallurgist of Surface Combustion Corp., Toledo.

CHARLES H. COLVIN has been elected to the board of directors of Avien, Inc. Colvin is president of Colvin Laboratories, Inc., East Orange, N.J., and has been active in the aircraft industry since 1913.

MAHLON E. WOOD has joined Reynolds Metals Co. as special representative in the aluminum firm's Automotive Market Sales Division. Prior to this new appointment, Wood was a manufacturing research engineer associated with many light metals developments at Ford Motor Co. Before joining Ford, he was with General Motors Corp. as materials engineer.

THOMAS C. GLEASON has been made chief engineer for electrical development and design in Chrysler Corp.'s Engineering Division. He had been assistant chief engineer for the electrical development and design section. Gleason joined Chrysler in 1935.

J. A. SCANLAN, assistant professor of mechanical engineering, University of Texas, is inaugurating a new course in nuclear powerplants, both stationary and mobile, as part of the graduate program at that institution.

L. L. COLBERT, president of Chrysler Corp., has been elected to the 150-member board of trustees of the Committee of Economic Development, a non-partisan economic research and development education organization.

WILLIAM T. SCHWENDLER, senior vice-president and a founder of Grumman Aircraft Engineering Corp., has been elected to New York University's board of trustees. Schwendler was chief engineer at Grumman from 1930 to 1950. He became a director of the aviation firm in 1939, a vice-president in 1940, executive vice-president in 1946, and senior vice-president in 1956.

THOMAS J. NEWTON, formerly product manager, Tire Division, United States Rubber Co., has been made director of private brand sales for the company.

Newton began in tire development in 1935. He has served as administrative assistant to the general manager of the Tire Division, and director of field engineering and service.

JAMES J. WELKER has been elected vice-president in charge of operations of Clevite Corp. For the past five years Welker has served as New York regional executive of Ford International, responsible for Ford operations in England and Germany.


Snead, Jr.


Ogden


Mitchell


McPherson


Colvin


Wood

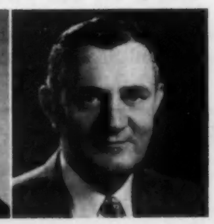

Gleason


Scanlan


McCortney


White


Hartmann


Cenzer

WILLETT J. McCORTNEY has been appointed director of automotive products development, General Tire & Rubber Co. Previously, he was manager, Organic Materials Laboratory, Chrysler Corp.

McCortney will be responsible, on a company-wide basis, for the new product development effort of the General Tire & Rubber Co. in the automotive field.

GEORGE H. WHITE has joined Leach Corp. as sales manager for the Pressure Switch Division. Formerly, he was field engineer, Wallace O. Leonard, Inc., Pasadena, Calif.

White has 15 years' experience in the fields of fuel, hydraulic, and pneumatic systems for airframe, engine and missile end-use.

In addition to his SAE activities, which include membership on the Governing Boards of both the Baltimore and Southern California Sections, he is also a member of the I.A.S. American Rocket Society, and the American Ordinance Association.

DONALD H. HARTMANN is now assistant to the president at Detroit Harvester Co. Formerly, he was with Packard in various engineering, product planning, and marketing capacities.

CARL W. CENZER has been appointed executive body engineer for American Motors Corp.'s automotive divisions. Cenzer, a 29-year veteran of the auto industry, formerly was chief engineer in charge of all AMC body activities. He was development engineer for Hudson Motor Car Co. from 1944 until the Nash-Hudson merger in 1954. Cenzer entered the automotive field in 1927 as a chassis-parts draftsman with Dodge Brothers.

FRANK J. OPATRNY has been appointed assistant sales manager for the Rubber Products Division of Parker Appliance Co., Cleveland. For the past eight years he was director of marketing with Perfection Industries Division, Hupp Corp. Before joining Hupp, he had been in field sales and service with Viking Mfg. Corp., Cleveland.

E. V. RICKENBACKER, chairman of the board of Eastern Air Lines, was recipient of the National Business Aircraft Association Merit Award for 1956.

A bronze plaque, citing Rickenbacker's outstanding initiative and leadership in development of air transportation, was presented on behalf of the association's board of directors.

D. W. SHERMAN has been made president of the newly formed A. O. Smith Engineering Service Corp., Milwaukee, Wis. Formerly, he was executive engineer of the A. O. Smith Corp.

The new company, which is a wholly owned subsidiary of the A. O. Smith Corp., will provide supplemental engineering assistance to the engineering staffs of the corporation's operating divisions.

Under Sherman's guidance, the company will undertake long range engineering design programs exploring the automobile frame of the future.

J. FRANK DRAKE, former president and retired chairman of the board of Gulf Oil Corp., was named 1956 recipient of the American Petroleum Institute's Gold Medal for Distinguished Achievement. Drake retired in April, 1955, as chairman of Gulf's Executive Committee, after having served five years as chairman of the board of directors, and 17 years as president. He is still a member of the Gulf board, and of its Finance Committee.

LOUIS C. LUNDSTROM has been appointed director of the General Motors Corp. Proving Grounds, which include facilities at Milford, Mich; Mesa, Ariz.; and Manitou Springs, Colo. Previously, he was assistant to the director of the company's Proving Grounds.

Lundstrom joined the Proving Ground staff at Milford as a test engineer in 1939. He was made project engineer in 1942, mechanical department head in 1947, and in 1953, was named assistant to the Proving Grounds' Director.

JOHN Q. HOLMES has been appointed director of the production engineering section at the General Motors Corp. Technical Center. He had been with the company's process development staff since 1954.

He joined the staff of Delco-Remy Division's process department as a designer in 1926. During World War II he was assistant chief engineer and master mechanic of GM's Eastern Aircraft Division.

Later, Holmes was made director of tool and process engineering in the central office of Buick-Oldsmobile-Pontiac Assembly Division, and served as master mechanic of the company's Kansas City, Kan., plant.

A. TOWELE, joint managing director, technical, Anglamol, Ltd., has been awarded the "Crompton Lanchester" medal for 1954–1955 by the Automobile Division Council of the Institution of Mechanical Engineers. He was honored for his paper entitled, "Some Problems in Lubrication and the Substances Called Additives."

Towele also has been elected to the Automobile Division Council of the Institution of Mechanical Engineers.

"Tab" Boyd Tells The Kettering Story

Boyd

Kettering

T. A. BOYD has just authored a biography of **CHARLES F. KETTERING**, titled "Professional Amateur." It carries an introduction by **ALFRED P. SLOAN, JR.** Dotted with direct quotes of the vivid comments on science and life for which "Boss Ket" is famous, the book bears witness to the author's long association with and great knowledge of his subject.

It covers the significant achievements of SAE's 1918 President from his traditionally American early life on an Ohio farm to the present. It is told with a wit and wisdom which match Kettering's own by his friend and associate of 40 years' standing. The book is published by Doubleday & Co., Inc.

JOSEPH M. BRIAN is now president of Brian Engineering, Ltd., Quebec, Can. He formerly was director of sales and engineering for Aviation Electric, Ltd. Brian has formed the new company to provide sales engineering service in Canada for the instrument, aircraft, and industrial fields.

VICTOR J. HARRIS is now a project engineer for Applied Design Co. in Buffalo. Formerly, he was chassis engineer, Dodge Division, Chrysler Corp.

L. EUGENE ROOT has been named a vice-president of Lockheed Aircraft Corp. and general manager of its Missile Systems Division. He formerly was director of development and planning at Lockheed.

B. A. CHAPMAN has been made executive vice-president and general manager of the Appliance Division of American Motors Corp. Previously, he was vice-president of operations for the company. **E. W. BERNITT**, who was vice-president of manufacturing and procurement, Automotive Division, becomes vice-president of operations for that division.

CHARLES E. JURAN is now preliminary design engineer, Grand Central Rocket Co., Redlands, Calif. Formerly, he was a 1st lieutenant in the U.S. Air Force at Norton Air Force Base, Calif.

GUY L. BLAIN, previously superintendent of operating garages for the Montreal Transportation Commission, will now be responsible for the preventive maintenance of autobuses, street cars, and trolley coaches for the Commission.

THOMAS R. STEFANCIN, formerly a designer, special development, Oliver Corp., is now a tool designer, B and M. Engineering Co., Burbank, Calif. Stefancin will design air frame assembly jigs and other production tooling.

BENJAMIN G. DAVIS, previously chief engineer, Edwards Trailer Co., Centerline, Mich., has been made head of the mechanical technology department at Mohawk Valley Technical Institute. Davis will have complete responsibility for both curriculum and instructional phases of the department.

F. A. KOTTMEIER is now a field engineer with Minneapolis-Honeywell Regulator Co. Previously, he was an industrial sales engineer with Shell Oil Co.

W. D. SIMS has been transferred from Shell Oil Co., Wood River Research Laboratory, Wood River, Ill., to Shell Development Co., Emeryville, Calif.

GORDON S. SHARPE has been made branch manager of the Midland Motor Corp., Ltd., in Northern Rhodesia. Prior to this new appointment, he was assistant technical editor, "Motor Transport" and "Bus & Coach," Iliffe & Sons, Ltd., London, England.

ROBERT J. GORMAN is now assistant managing engineer, hydraulic drive and advanced development, transmission and hydraulic drive laboratories, Engineering Division, Chrysler Corp. He will be responsible for all development and testing concerning torque converters, fluid couplings, and advanced hydraulic drive and transmission designs.

IVAN R. JOHNSON has been made assistant managing engineer, current transmission development, at the transmission and hydraulic drive laboratories. He will be responsible for the development and testing of automatic transmissions which have been scheduled for future production.

PAUL P. ALPER has joined Walter Kidde & Co., Inc., as scheduling and planning supervisor. Previously, he was an industrial engineering analyst at Wright Aeronautical Division of Curtiss-Wright Corp.

In this new position, Alper will organize a new group to plan and schedule the efforts of research and development projects in the aircraft auxiliary powerplant field.

WALTER M. MASON is now resident field engineer, Lincoln Division, Ford Motor Co., San Mateo, Calif. Formerly, he was district manager, Chrysler Division, Chrysler Corp.

Mason has been in the automotive field since 1939 when he joined the ACF-Brill Motors Co. as a sales trainee. He was made a service engineer in 1946, and sales representative in 1948.

He served in the U.S. Army as 1st lieutenant, automotive officer, Ordnance in 1949. He joined Chrysler as district manager in 1950.

E. L. DAHLUND has been made a manager of engineering for the Albuquerque plant of the Nuclear Products Division of ACF Industries, Inc. Prior to joining ACF, he was chief engineer, diesel engineering department, Fairbanks, Morse & Co.

D. ROY SHOULTS has been elected a director of American Standards Association, representing the Aircraft Industries Association. Shoults is general manager, aircraft nuclear propulsion department, Atomic Products Division, General Electric Co.

J. W. LANE, manager, Automotive Division, Socony Mobil Oil Co., Inc., has been elected president of the National Lubricating Grease Institute.

J. RALPH HOLMES, previously chief engineer, Harrison Radiator Division, General Motors Corp., has been named to the newly created post of technical assistant to the general manager. **LAWRENCE A. ZWICKER** will succeed Holmes as chief engineer of the division. Formerly, he was assistant chief engineer for product engineering.

ROBERT GRAY has been appointed supervisor, technical service, Western Division, Tidewater Oil Co. Prior to this new appointment, he was assistant sales manager for Frank Edwards Co., San Francisco.

He will provide technical service to company customers and act as liaison between marketing, engineering, and manufacturing department of the division.

Gray's SAE activities include membership on Cleveland Section's Board of Governors in 1949, and Northern California Section's Board of Governors in 1951.

ROLAND C. BERGH, chief staff engineer at Republic Aviation Corp., has been named full-time director of the company's jet-noise-suppression program. Bergh has been with Republic for 21 years, and for the past two years has worked on the noise suppression program, along with his other duties.

DAN McCANN is now president of McCann Engineering Co., Los Angeles, Calif. Previously, he was armament engineer, Consultants & Designers, Inc., New York.

BURTON K. SNYDER is now an associate mechanical engineer in the Central Shops of Argonne National Laboratory. Previously, he was a design engineer with Johns-Nigrelli-Johns.

KENNETH IAN MORTON has joined Pacific Motor Trucking Co. as a serviceman. He had been a service engineer with John Burns and Co., Ltd., Machinery Distributors.

J. PERCY BICKELL, previously registrar of motor vehicles for the Ontario Department of Highways, has retired.

Bickell held the position of registrar of motor vehicles since 1916, when it was created. He joined the civil service in 1906 as a clerk for the provincial secretary. Bickell will continue to act as consultant to the motor vehicles branch.

PO-LUNG LIANG is now with the engineering staff of Ford Motor Co. Previously, he was with Studebaker-Packard Corp.

LOUIS KLEIN, JR. is now personnel representative, engineering, Solar Aircraft Co., San Diego. Previously, he was assistant professor, aeronautics, at Utah State College.

Klein has served as Student Committee chairman for the SAE Salt Lake City Group, and also served as faculty adviser for the SAE Student Club at Utah State College.

CHARLES E. SHIELDS is now a design and development engineer with the Radio Corp. of America. Previously, he was a development engineer with Syntron Co.

MELVIN S. LANTZ is a product application engineer with Cummins Engine Co., Inc., Columbus, Ind. He had been a Second Lieutenant with the Department of the Air Force, Sidney, Ohio.

GEORGE B. COOVER is now in the engineering recruiting department at General Electric Co. He had been an application engineer in the aircraft accessory turbine department at General Electric.

FRED D. WILSON is now a project engineer, missile operations, Chrysler Corp. Formerly, he was with the Tractor and Implement Division of Ford Motor Co. as a project engineer.

NELSON J. KREIDER is a project engineer, electro-mechanical, Avionic Division, John Oster Mfg. Co., Racine, Wis. His previous position was chief engineer and general manager, Dexter Machine Products Inc., Chelsea, Mich.

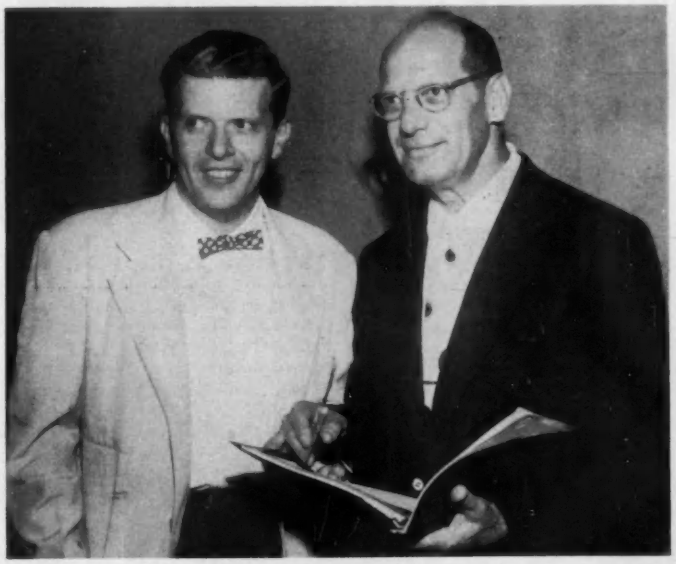
STUART A. CAMERON is now a design engineer with Hunter Engineering Co., Riverside, Calif. He attended New Mexico College of Agriculture and Mechanic Arts. Cameron will work on instrumentation design.

JOHN M. ROOP is now a service engineer with the Ford Division of Ford Motor Co. Prior to joining Ford, he was maintenance officer, 1st Motor Training Squardon, Department of the Air Force.

GEORGE EWDOKIMOFF has joined Bell Aircraft Corp. as a structures engineer. Prior to this appointment, he was senior body draftsman, Central Engineering, Chrysler Corp.

ROBERT N. COLLINS is now an instructor in the mechanical engineering department at the University of Wisconsin. He had been a research engineer with Continental Oil Co., Ponca City, Okla.

SAE Father and Son



ALBERT HOLZWASSER (right), president of Arrow Armatures Co., Boston, and SAE Publicity chairman for the New England Section, discusses committee work with son **HARRY HOLZWASSER** (left).

Harry, a recent SAE acquisition, is sales manager at Arrow Armatures. He joined the company shortly after his return from ETO service in England, France, and Germany during World War II.

The Elder Holzwasser is now serving his second term as chairman of the National Standard Parts Association's Rebuilders Division. His activities in the automotive after-market include posts on the Anti-Monopoly Committee.

Greets New GM Stockholders

E. N. COLE (left), general manager of Chevrolet Motor Division, General Motors Corp., and **E. H. KELLEY**, manufacturing manager, are shown in conference with an important group of new General Motors stockholders.

The new investors, 60 highschool freshmen from Washington Irving School, Tarrytown, N. Y., pooled some 77 cents each to buy a share of stock as a class project.

The Class of 60 Stock Co. took opportunity to talk with Chevrolet officials on their visit to Tarrytown to mark the production of the 36,000,000th Chevrolet.

Both Cole and Kelley are past vice-presidents of SAE.

LAWRENCE A. ZAHORSKY has been named chief components project engineer, White-Rodgers Co., St. Louis, Mo. Formerly, he was chief motor project engineer, Lear, Inc.

Zahorsky has served as chairman of SAE Aircraft Electrical Motor Sub-Committee A-2M, and was a member of SAE Aircraft Electrical Committee A-2.

DONALD R. LONG has joined the engineering staff of General Motors Corp. as a design engineer. Formerly, he was an instructor in the department of mechanical engineering at the University of Washington.

Long was vice-chairman of the SAE Student Branch at the University of Michigan in 1947.

JAMES E. GETZ is now assistant project automotive engineer at Standard Oil Co. of Ind. Formerly, he was mechanical engineering research assistant, Ballistics Research Laboratory, Aberdeen Proving Ground, U.S. Army.

EUGENE V. GRUMMAN has been appointed general superintendent for the Bullard Co. of Bridgeport, Conn. Previously, he was manager of quality control for the company.

Grumman joined Bullard in 1943 as a sales contract engineer. Since then he has held various positions including process engineer, project engineer, supervisor of experimental development and research projects, and manager of the Subcontract Machining Division.

F. E. WHERLEY is now service manager with Logan Mayhew, Ltd., Vancouver, British Columbia. Formerly, he was service manager for Ferguson's Tractor and Equipment Co.

JOSEPH R. LEJK, previously a senior engineer in the research projects department of the Central Engineering Division of Chrysler Corp., is now a development engineer in the products engineering department of the Trane Co.

DONALD J. MATHIAS is now mechanical design engineer, Convair-Pomona Division, General Dynamics Corp. Formerly, he was a junior project engineer, Moraine Products Division, General Motors Corp.

WALTER SWARDENSKI has been made director of purchasing for Caterpillar Tractor Co., Peoria, Ill. Prior to this new appointment, he was manager, purchasing general office, for the company.

RICHARD R. LOVELL has joined Bendix Products Division, missiles, Bendix Aviation Corp. as spare parts supervisor in the project engineering group.

PROF. ALFRED DEL VECCHIO is now in charge of a newly formed curriculum leading to the degree of bachelor of mechanical engineering at Manhattan College. Del Vecchio has been a member of the Manhattan staff since 1946.

CHARLES H. KANAVEL has been appointed field sales manager for B. F. Goodrich Aviation Products, a division of the B. F. Goodrich Co. He had been western zone manager, aeronautical sales, for the company. Kanavel has been with Goodrich since 1933. During World War II, he served as assistant manager of government sales in Washington, and later as manager of the war products department. After service as manager of the industrial Tire and Track Division in Akron, he was transferred in 1946 to Los Angeles where he became district manager for equipment sales. He was appointed western zone manager, aeronautical sales, in 1954.

HARLOW H. CURTICE, president of General Motors Corp., was the principal speaker at the annual dinner of the American Institute of Consulting Engineers.

RICHARD J. WILLS has been made field supervisor at General Electric Co. Previously, he was a field engineer with Sperry Gyroscope Co.

HARRY BAUM has been named project manager in the Technical Writing Service of the McGraw-Hill Book Co. He has been with the Technical Writing Service since 1954.

Baum has also been elected to the board of directors of the Society of Technical Writers as district delegate from New York and New Jersey.

WALTER J. HUCK, who was laboratory supervisor, Long Mfg. Division, Borg-Warner Corp., has been made supervisor of special projects and testing for the division. He will supervise test setups and performance testing of new company products and designing of test equipment.

Ford Engineering

The positions now held by 11 SAE members involved in recent additions to or changes in the Ford engineering staff are:

HARLEY F. COPP, assistant chief engineer, product engineering office, Ford Division;

ROBERT STEVENSON, director, engine and electrical engineering, Engineering Staff;

HAROLD C. MacDONALD, chief engineer, product engineering office, Mercury Division;

HAROLD W. JOHNSON, chief engineer, product engineering office, Lincoln Division;

J. W. FRENCH, executive engineer in charge of advanced engineering, Special Products Division;

ROBERT B. ALEXANDER, design engineer, components engineering department, special products engineering, Special Products Division;

ROBERT O. WILLIAMS, design engineer, components engineering department, special products engineering, Special Products Division;

PAUL E. CHUBA, development engineer, components engineering department, special products engineering, Special Products Division;

G. G. DESCAMPS, development engineer, car engineering department, special products engineering, Special Products Division;

ROBERT R. PETERSON, assistant department manager, car engineering department, special products engineering, Special Products Division;

BENN D. KELLER, assistant department manager, Arizona Proving Ground;

LEROY H. FRAILING, technical assistant, Michigan Proving Ground.

JACK RYAN, JR. is now service manager for Denny Gilstrap Ford Co., Connersville, Ind. Previously, he was a service representative and instructor for Ford Motor Co.

I. S. VAN WART has joined Boeing Airplane Co., Seattle, Wash., as a design engineer. Previously, he was a project engineer with Chrysler Corp.

ALFRED S. JOSSI is now a research engineer with Convair Astronautics Division, General Dynamics Corp. Before joining Convair, he was senior engineer, defense engineering, Chrysler Corp.

Jossi has served as chairman of the Junior Section Speakers Committee in the SAE Detroit Section.

GEORGE F. DIXON, previously with the Clark Equipment Co., is now missile mechanical systems engineer for Boeing Airplane Co. at the Air Force Missile Test Center, Patrick Air Force Base, Coco, Fla.

EUGENE S. MURPHY is now a project engineer with Rockford Clutch Division of Borg-Warner Corp. Prior to joining Borg-Warner, he was a project engineer with Allison Division of General Motors Corp.

WALTER A. HORNER, JR. is now assistant staff engineer, production, Chevrolet Motor Division, General Motors Corp. He had been resident engineer for Chevrolet Division.

PRESTON T. TUCKER, JR. is now senior manufacturing engineer for Rocketdyne Division of North American Aviation Co. Formerly, he was assistant general manager, Ypsilanti Machine and Tool Co.

RALPH B. BEARDSLEY has been made factory manager for Ramsey Corp., St. Louis, Mo. Previously, he was project manager at the Piston Ring Division, Thompson Products, Inc.

H. A. FRANKE, manager of the automation department of the Ford Stamping Plant, Buffalo, New York, delivered a talk entitled "Automation for Stampings" before a meeting of the Teachers of the State of New York on October 26, in Buffalo.

Franke pointed out why automation has found its usefulness in American industry, and how it has already raised the nation's standard of living. He called on educators at the high school level to encourage young men to adopt engineering as a career. Franke predicted that in 1975 the population of the United States will be around 220 million and that only with improved machines—automation—can we maintain and improve our standard of living while trying to supply this potential market.

He described operations at the Ford Stamping Plant which are based on the concept of production as a continuous flow rather than processing by intermittent batches or work. Many burdensome hand operations have been eliminated, making it possible to operate the equipment faster and with more safety.

Franke is chairman of the SAE Production Forum which will be held in Buffalo, March 20–22, 1957.

Kinzel

DR. AUGUSTUS B. KINZEL, vice-president in charge of research at Union Carbide and Carbon Corp., has been elected 1958 president of the American Institute of Mining, Metallurgical, and Petroleum Engineers.

Dr. Kinzel has been actively engaged in research work with Union Carbide for the past 30 years. His research contributions have covered a wide range of activities in the fields of metallurgy, industrial gases, and atomic energy.

One of the country's leading research metallurgists, Dr. Kinzel pioneered in the theory of stainless steels. His work on deoxidizing and alloying elements pioneered the structural low alloy steels and new ferro alloys and provided major advances in the welding and cutting of steel. Recently, he spearheaded the research that led to the development of Union Carbide's new process for making titanium metal. More than 40 patents have been issued in his name.

BURKE STARKS has been made master engineer, powerplant, Mid-Continent International Airport, Trans-World Airlines, Inc. Previously, he was senior engineer, powerplant, at Mid-Continent International Airport.

FLOYD O. MILES has been made general manager, wholesale marketing department, D-X Sunray Oil Co., a subsidiary of Sunray Mid-Continent Oil Co. Previously, he was executive vice-president and manager of Valley States Oils, Inc., also a subsidiary of Sunray Mid-Continent Oil Co.

O. E. RODGERS has been made chief engineer, Utica-Bend Corp., a subsidiary of Curtiss-Wright Corp. Prior to this new appointment, he was assistant general manager and chief engineer, Government and Industrial Division, Studebaker-Packard Corp.

Rodgers was a member of the SAE Aircraft Engine Division for a number of years.

SAE CEP

COOPERATIVE ENGINEERING PROGRAM **NEWS**

To Assist Technical Board . . .

. . . two new committees are pointing toward more active and more uniform handling of technical committee projects and publications.

. . . by . . . **Trevor Davidson**
Chairman
Technical Committee
Guideposts Committee

C. F. Arnold
Chairman
Technical Board
Publication Policy Committee

THE SAE Technical Board has established two new committees.

One of these will develop and suggest guideposts for operation of SAE technical committees. The other will establish policies relative to publication of technical committee reports.

The two groups are the Technical Board's response to a need increasingly recognized by members long associated with technical committee activities. Experienced workers on such committees, through constant exposure to procedures existing in particular committees, have learned to steer their committees successfully by intuition. But they have not always been able to operate with a minimum amount of lost motion.

Both new committees are already hard at work developing their recommendations for the Board.

THE TECHNICAL COMMITTEE GUIDEPOSTS COMMITTEE is working toward a well-focused description of successful technical committee operations, which would include:

(1) Objectives of technical committee activities (such as development of standards and other technical publications);

(2) Outline of requirements for preparation of a scope for a committee;

(3) Description of requirements for committee membership—and responsibilities of committee members;

(4) A recommended organization for a typical technical committee;

(5) Description of duties of committee officers and of the functions of an SAE staff representative;

(6) Typical procedures illustrating the handling of a project (including instructions on meetings, agendas, minutes, and voting);

(7) Relationship of SAE technical committee representation on outside activities (such as ASA, ASTM, CRC, and others).

The suggested guideposts will include definitions of the various types of publication which might result from technical committee activity. These will guide technical committees to select the most appropriate means of conveying their work to the Society.

THE PUBLICATION POLICY COMMITTEE of the Technical Board, functioning on a permanently active basis, will guide and promote the effective dissemination of material produced under Technical Board auspices.

At its first meeting, the PPC discussed, for example, the advisability of changing the Handbook publication date from its traditional May to December. As a result, the PPC favors this change. Its chief reason: January Handbook publication would shift to the June Technical Board meeting final approval of projects to be included in the Handbook. Thus nine solid months from September

to June would be available for development of projects by technical committees. (Currently, these final approvals must come at the Board's January meeting . . . and the nine months preceding that meeting include three summer months which, in a practical sense, are not available for progress on technical committee projects.)

Other reasons for favoring the change, include:

(1) The change would have the effect of advancing publication date of approved reports; and

(2) Issuance shortly after annual dues payment will tend to increase appreciation of members of the services offered by the Society.

Only drawback PPC can see to changing the Handbook publication date from May to December is temporary in character. In the year that the shift is made, the preceding Handbook will have to remain in effect for about 18 months.

To insure full exploration of the Handbook publication date problem, PPC is canvassing the chairmen of all SAE technical committees to get their reactions. All comment from committee chairmen will be submitted to the Technical Board by the PPC along with its own recommendations.

PPC, in its early deliberations, has also recognized lack of publicity for new technical reports and recent changes in existing standards as one shortcoming in current technical committee procedures. So, it will explore possible changes of method for keeping SAE members informed. Under consideration are such possibilities as news letters and more active use of SAE Journal facilities for bringing Society news to members.

PPC hopes also to develop policies on the issuance of technical committee reports in advance of Handbook publication, where sufficient urgency exists to warrant interim publication.

To sum up, PPC is trying to increase the SAE's value to its members by focusing attention on material available from technical committee activities. It hopes also to aid in enlisting active support for future technical committee development.

CRC Tests Hot-Weather Fuel-Performance Action

A TECHNIQUE for the evaluation of hot-weather fuel-handling difficulties in passenger-car operation is presented in CRC report (CRC-289), "Passenger-Car Hot-Weather Fuel-Handling Difficulties—Indio, California, 1953."

Investigation of acceleration performance, hot-starting, idle performance, and city-traffic operation was made under very specific conditions. Tests were run on eleven 1952 and 1953 cars to establish performance-limited fuel volatilities on both a pentane and a butane fuel series.

The following conclusions were made as a result of this analysis:

1. No single type of operation employed in these tests detects the minimum hot-weather fuel-handling ability of all vehicles.

2. The fuel volatility for the limiting type of operation in each car, as expressed in terms of Reid vapor pressure, was consistently lower on the pentane fuel series than on the butane fuel series. However, the differences in these minimum Reid vapor pressure values between the two series of fuels were not uniform from car to car, nor from one type of operation to the other.

In general, the test results on these cars show that:

1. In acceleration tests there is greater hot-fuel-handling difficulty with increasing fuel volatility. The minimum Reid vapor pressure at which difficulty was encountered was lower in most cases using the pentane fuel series.

2. Hot-starting performance appears independent of vapor-forming characteristics of the fuel within each fuel series. But quicker hot-starting is given with the butane fuel series.

3. During idle test in which stalling and/or lock is encountered, there is a greater tendency to stall and/or lock on the higher volatility fuels of the pentane series. Since stalling was encountered in only one instance using the butane fuel series, idling performance is considered independent of fuel volatility for this fuel.

4. During city-traffic tests where stalling and/or lock occurred, there was a greater tendency to stall and/or lock on the higher volatility fuels of the pentane series. Since there was no stalling or lock for the butane series, it is concluded that performance is independent of fuel volatility within the range tested.

CRC-289 contains 160 pp, including graphs, charts, and tables. It is available from SAE Special Publications Department. Price: $5 to members, $10 to nonmembers.

Bonas Retires; Receives Plaque

At a recent meeting of SAE Committee A-4, Aircraft Instruments, the retiring chairman, **William K. Bonas** (left) was presented by the committee with a plaque in appreciation of his fine efforts and cooperation in their behalf. **William B. Bergen** (right), executive vice-president of Glenn L. Martin Co. made the presentation.

Frey Congratulates Frey . . .

DR. DONALD N. FREY, associate director, Scientific Laboratory, Ford Motor Co., Engineering Staff, received the Russell S. Springer Award for being the youngest author of a paper published in the 1956 SAE Transactions. His paper, "New Alloys for Automotive Turbines," was presented at the SAE Annual Meeting, Detroit, Jan. 10, 1956.

Presentation at Detroit Section

The presentation was made on November 19 at a meeting of the Detroit Section. Russell F. Sanders, vice-chairman of the Section, introduced Muir Frey, who then surprised his son by making the presentation. Muir Frey is the 1957 SAE vice-president-elect for Engineering Materials Activity.

The Springer Award, established by the SAE Council in 1954, grew out of a $5000 bequest to the Society by the late Russell S. Springer. As winner of the Award, Dr. Frey received $100 in addition to a plaque.

Muir L. Frey (left) congratulates his son, Dr. Donald N. Frey, after presenting him with the Russell S. Springer Award for 1956 at a meeting of the Detroit Section on November 19.

MICHELL Gives 1956 Buckendale Lecture

William P. Michell (third from left), chief development engineer, Toledo Division, Dana Corp., is shown receiving plaque from SAE Past-President Dale Roeder (second from left), who was chairman of the Buckendale Lecture Committee that chose Michell to give the Lecture. At left is E. P. Lamb, present chairman of the Buckendale Lecture Committee. To the right of Michell are E. P. Petsch, member of the Committee, and Read Larson, vice-chairman of Student Section Activities, SAE Metropolitan Section. The Met Section sponsored the meeting at which the Lecture, "New Drive Lines for New Engines," was given, on November 20.

SAE National Meetings

1957

January 14-18
Annual Meeting and Engineering Display
The Sheraton-Cadillac and Statler Hotels
Detroit, Mich.

March 5-7
Passenger Car, Body, and Materials Meeting
The Sheraton-Cadillac
Detroit, Mich.

March 20-22
Production Meeting and Forum
Hotel Statler, Buffalo, N. Y.

April 2-5
Aeronautic Meeting,
Aeronautic Production Forum
and Aircraft Engineering Display
Hotel Commodore, New York, N. Y.

June 2-7
Summer Meeting
Chalfonte-Haddon Hall
Atlantic City, N. J.

August 12-15
West Coast Meeting
Olympic Hotel, Seattle, Wash.

September 9-12
Tractor Meeting and Production Forum
Hotel Schroeder, Milwaukee, Wis.

October 1-5
Aeronautic Meeting,
Aircraft Production Forum,
and Aircraft Engineering Display
Ambassador, Los Angeles, Calif.

November 4-6
Transportation Meeting
Hotel Statler, Cleveland, Ohio

November 5-6
Diesel Engine Meeting
Hotel Statler, Cleveland, Ohio

November 6-8
Fuels and Lubricants Meeting
Hotel Statler, Cleveland, Ohio

Motor Coaches of 1961 to Sport Many New Features

Based on paper by

R. H. BERTSCHE

GMC Truck and Coach Division,
General Motors Corp.

THE heavy transit coach and the intercity coach of five years hence will be "horses of a different color" sporting many new features.

The future heavy transit coach will be equipped with an exterior lighting system consisting of four head lamps and the usual corner markers with perhaps two additional amber side markers; front, side, and rear directional signals; and, two tail lamps and two stop lamps. These will have improved photometric characteristics and some may use larger bulbs which will be mechanically improved to reduce the time required to rebulb when necessary.

The interior will be lighted by a fluorescent system providing an attractive, comfortable, warm white light, shadowless and without glare. Minimum incandescent standby lighting with automatic changeover will be provided. To increase the legibility of the destination sign, it too will be equipped with fluorescent tubes.

The driver's instrument panel will contain an air gage and an electric speedometer which is different from ones now in use and which has specifically been designed to run a very long time without attention. Telltale lights of an enunciator system will warn the driver of unsafe operating conditions.

The coach will be equipped with an efficient heating and ventilating system designed to supply an adequate amount of fresh heated air. This system will be automatic in operation and will be one of the major consumers of electric power.

All motors will be of high grade construction with sealed ball bearings and will require little attention and no lubrication for long periods of time.

Rear doors will be of the push type eliminating the need for electrical safety equipment such as treadles and sensitive edges.

The very heavy electrical load of this coach will be supplied by an engine driven alternator which must be able to carry the major part of the load at idle. This machine will require something other than conventional cooling and will be enclosed to protect it from foreign substances. It will be designed and built to run between engine overhauls without attention or lubrication. It will be controlled by a static voltage regulator which will give very close control and which will go for very long periods of time, perhaps even the life of the coach, without attention.

The starting system will be electric, with an improved 12 or 24 v starting motor. This unit will also be capable of going without attention between engine overhauls.

The battery will be of the lead acid type and in spite of the much greater electrical requirements of the coach, will not be larger and may even be smaller than present batteries. Because of generator and regulator characteristics, it should not require as much attention as it does at present.

The typical intercity coach of the same year, particularly those in long distance express service, will have exterior lighting systems the same as those on the transit coach. Reading lamps will continue to be the incandescent spot type now used. General lights may be of the fluorescent type powered from a 60 cps inverter which will be required for other equipment.

Heating and cooling systems will be improved in detail but will essentially be the same as at present.

Some form of passenger entertainment such as tape players or radios, neither containing vacuum tubes, will be provided. Many coaches will use public address systems equipped with static amplifiers which use neither transistors nor vacuum tubes. Television may also be used although many engineering problems must first be solved.

Lavatories will be quite common and some form of good service will be provided. This may take a form similar to that used by the airlines or be done by automatic dispensing machines. In either case electrical refrigerating and heating units will be required. These will probably be adaptations of 60 cps commercial units whose current requirements will be supplied by an inverter run from the coach electrical system.

The primary source of current will be an engine driven alternator similar in design to that used on the transit coach. In order to standardize, it is

probable that the same machine will be used on both types of vehicles. Other items of electrical equipment will be the same or similar to that used on transit coaches and will be designed and built to have the same reliability and freedom from maintenance. (Paper "Trends in Motor Coach Electrical System" was presented at SAE National Transportation Meeting, Oct. 1956. It is available in full in multilith form from SAE Special Publications Department, 485 Lexington Ave., New York 17, N. Y. Price: 35¢ to members, 60¢ to nonmembers.)

Servo Test Provides Mock Flight Conditions

Based on paper by

GEORGE R. KELLER

and

ELLIOTT R. BUXTON

North American Aviation, Inc.

A DYNAMIC load simulator, designed for loading a servo for ground testing under flight conditions, is shown in Fig. 1. The servo moves a bellcrank to which are attached large over-hung weights. These weights represent the inertia of the surface.

Movements of the bellcrank from its neutral position also force oil out of loading cylinders into air-oil accumulators. Compression of the air furnishes a spring reaction force which simulates the wind-loading of the surface. The rate of this loading varies with flight altitudes and Mach Number, and the variation can be provided on the simulator by changing the air pre-load pressure in the accumulator. By using proper test instrumentation, the dynamic transient and frequency response characteristics of the servo can be tested over all expected flight conditions.

The culmination of the ground testing comes when the techniques of the power servo engineer and the dynamicist are wedded. This can be done, among other ways, by coupling load simulators to analogue and digital computors and to the electromechanical portions of the flight control system. The airframe equations are mechanized on the computers. Flight programs can be fed into the computers and the airframe effects applied to the flight control sensing elements. Corrective signals are then applied to the servos. The proper performance of the servos then proves the complete system.

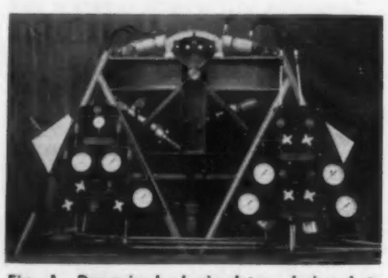


Fig. 1—Dynamic load simulator, designed to load a servo for mock flight testing. Can be used to simulate all expected flight conditions.

This proving system is particularly useful when environmental conditions such as temperature and pressure variations can be applied to the load simulator. In such cases, the whole train of development thought—from the aircraft dynamics through the component and system design to the flight environment—can be tested for service validity. (Paper, "The Synthesis of Aircraft Hydraulic Servos" was presented at SAE National Aeronautic Meeting, Los Angeles, October 1956. It is available in full, in multilith form, from SAE Special Publications Department, 485 Lexington Ave., New York 17, N. Y. Price: 35¢ to members; 60¢ to nonmembers.)

New Wings Need New Production Techniques

Based on a report by

W. R. SLAGG

Northrop Aircraft, Inc.

NEW airplanes require wings designed specially for their new high speed functions. For example, the fighter plane—with its thin wings and high loading intensity—needs a thick integral skin wing, while the transport plane needs a stringer skin design. Other airplanes fit into the intermediate group calling for various combinations of both.

Old type wing designs and new loading requirements would necessitate wings of immense weight. However, recent development of material, production, machining techniques, and a bolder approach to the design allows us to obtain more favorable wing weight-load ratios.

For example, the engineer can make a topographical map of stress distribution in a thick skin wing panel. Automatic skin milling machines can duplicate the required skin gages as taken from the topographical map.

Forming of heavy skins poses problems, particularly where contouring to a high degree is required. Of the many forming techniques, such as rolling, braking, stretching, and shot peening, each has its application. On most thin wings the structural skins require only a small amount of contouring. During the machining of integral skins a certain amount of residual stresses, built into the material during its manufacture, can be relieved, giving a slightly contoured skin. In addition, since the parts are not completely contoured, the remaining contouring can be accomplished during the final assembly operation. This causes a splinning effect to take place over the skin surface, thus giving a rather smooth, wave-free contour.

The forming of heavy skins in jigs actually builds a certain amount of stress into the wing skin. However, in thin, highly stressed wings, the upper and lower skins are very nearly the same gage, so most of these residual stresses are balanced between the upper and lower surfaces. The rest are left to rib design. Since stringers, rib caps, spar caps, and main wing attach fittings are integral with the skins, fatigue is reduced.

Six rules for designing and manufacturing modern aircraft wings at reasonable cost are as follows:

1. The new design should be studied and analyzed before release, for the purpose of:
   a. Reducing the necessity for assembling in enclosed areas.
   b. Eliminating complicated bayonet type carry-through fittings.
   c. Reducing the use of right-angle drilled clips.
   d. Eliminating as many shims and doublers as possible.
   e. Reducing the number of parts which have to be hand-located.
   f. Determining the need for new or special tools, equipment, and processes.
2. Schedule prototype as early as possible and accelerate slowly in order to allow time for corrective action.
3. Set up an aggressive follow-up program to correct errors and assist in solving manufacturing difficulties.
4. Time studies should start with the first airplane in order to pinpoint these operations which offer the greatest opportunity for making improvements which will result in cost reduction.
5. Manufacturing Supervisors should develop rough job breakdowns prior to start of assembly. These should be refined on first and subsequent assemblies and used for worker assignment.
6. Each supervisor should work to a direct labor budget, which is his share of hours allocated from the estimates made for the whole assembly. Reports should be issued regularly showing performance against these budgets.

(This article is based on the secretary's report of the panel **Wings** which was presented at the SAE Aeronautic

Continued on page 109

SECTIONS

JANUARY 1957

Arrangements Committees Tackle Reservations Problem

Financial loss caused by dinner attendance on meeting-nights not coming up to minimums guaranteed to the hotel is not a problem with Montreal Section.

Success in avoiding loss is attributed to two factors—a well organized and live telephone committee working under membership chairman G. L. Blain, and a very diplomatic and persuasive arrangements chairman Maurice Bourgault.

The telephone committee is large enough to give each member only nine or ten names to call. Rule number one for the committee is that phone checks will be made by committee members and not their secretaries. Each telephoner's list is made up of members whom he contacts fairly regularly in his daily business. This helps to get more members out to meetings and assures a more accurate forecast of attendance.

Phone committeemen report their attendance promises to arrangements chairman Bourgault who makes up the total forecast and discounts it judiciously before making final arrangements with the hotel's head chef.

Chairman Bourgault aims at keeping his forecast just a little under actual attendance. (The hotel can always find food for the unexpected guest!) This keeps relations with the head chef on a cordial basis and assures the Section of his understanding cooperation on the rare occasion when attendance does slip under the guarantee.

Reservations by Telephone

A similar solution to the problem was evolved by members of the Arrangements Committee in the Washington Section. For the past two years, that Section has required that reservations be made by telephone with a deadline of a day before the meeting. An estimate is provided for the hotel with roughly a 10% increase over the number of telephone reservations. The telephone reservation service in the Washington Section is provided through the courtesy of one of the companies whose representatives are active Section participants.

Other Sections' Arrangements Committees, for the most part, work through a system of dinner reservation cards plus a reasonable discount for those who promise to but don't attend. Several Sections have an understanding with the hotel that a plus or minus difference of approximately 10% will be tolerated.

Last-Minute Guarantees

San Diego and Southern California Sections have succeeded in securing a last minute guarantee arrangement. Southern California Section, at noon on the day of the meeting, gives a guarantee to the hotel, based on actual reservations received to that hour, less 10% for no-shows, but asks the hotel to set up for approximately 15% more than the number guaranteed. The Section continues to take reservations and cancellations by phone until 4:00 p.m. and gives the final guarantee at that time.

Metropolitan Section Arrangements Committee members feel that they have solved their particular problem by taking the meetings out of the hotels and holding them in a restaurant that is looking for this type of business. The restaurants have been more cooperative than hotels in the matter of dinner guarantees. As a result of this policy, Metropolitan Section has not had to pay for a single unclaimed dinner at any of its regular dinner meetings.

Some Sections, in an effort to make members more conscious of the reservation problem, charge a standard price for advance reservations, and a higher price for those sold at the door. One Section accepts only reservations which are accompanied by a check to cover the price of the dinner, while another Section sells dinner tickets in advance of the meeting. Ultimately, the solution to the problem of unmet guarantees lies with the individual members. A greater awareness on the part of members that unpaid dinner reservations is a drain on the entire Section will, undoubtedly, arouse in each member a sense of responsibility to the other members and enable the Section's Arrangements Committee to operate more effectively.

From Section Cameras

1. **E. E. Klein** (right), contact engineer in the engineering department of Argonaut Realty Division, General Motors Corp., describes a plan of the GM Technical Center at the Nov. 12 joint meeting of **Syracuse Section** and the Technology Club of Syracuse. Standing left to right are: **L. Schnaufer**, Argonaut Realty Division, General Motors Corp.; **Edward Hannon**, Section vice-chairman; **Prof. William P. Crane**, president, Technology Club of Syracuse; and **Richard Sturley**, Section Meetings chairman.

2. **Mid-Michigan Section Chairman Earl Wilson, Jr.** (right) and Section Program Chairman **Frank Pritchard** (left) pose for a photo at the Section's Nov. 5 meeting with guest speakers **Thomas J. Defoe** (center left), vice-president and general manager of Defoe Shipbuilding Co., and **E. A. Anderson** (center right), Commander USNR, resident supervisor of shipbuilding at Defoe.

The meeting included a tour of the Navy's newest destroyer escort now under construction, the "USN Lester."

Defoe related the many problems involved in the construction of the destroyer escort and methods used to cut time and expense in getting out the finished vessel, while Anderson described the latest improvements which resulted in higher crew morale and conveniences throughout the ship.

Salt Lake City

J. C. Bates, Field Editor

Present trends in passenger-car design, truck design, earth moving equipment design and the effect of such trends upon tire design was the theme of a talk given at the Nov. 19 meeting of the Salt Lake City Group. Guest speaker was **K. L. Campbell**, manager of truck tire engineering for the Firestone Tire and Rubber Co., Akron, Ohio.

CANADIAN

F. G. King, Field Editor

"The Story of the Tubeless Tire" was unfolded by **William B. Flora**, vice-president, sales, B. F. Goodrich, Canada Ltd., at the November meeting of the **Canadian Section.**

Special guest at the meeting was **J. L. Stewart**, who was presented a certificate honoring his 25 years of membership in SAE. Stewart served as chairman of the Canadian Section in 1933–1934.

WICHITA

K. W. Rix, Field Editor

Wichita Section members heard three representatives of Lear, Inc. discuss three different phases of air power at the Section's November meeting. **W. W. Williams**, chief design engineer, rotary actuators and servos, spoke on "Air Motor Powered Actuation Systems." **William Stubbs**, project engineer, air inlet and thrust reversers, presented a paper entitled "Supersonic Air Inlet Controls." **Dunstan Graham**, project engineer of automatic flight controls, gave a talk on "Automatic Flight Controls."

Philadelphia

E. V. Henc, Field Editor

SAE Student members were in the spotlight at the November meeting of the **Philadelphia Section.** Student Activity Chairman **Karl Green** outlined to the student membership the four related fields in which Philadelphia Section participates, namely, Truck and Bus, Transportation, Aircraft, and Fuels and Lubricants.

Green further elaborated on the activity of SAE in each of the fields, thus giving the engineering students a vision of what the Society is doing and some of its goals.

William Kaplan, American Oil Co., commented on the sports car trend in America and presented a color film of the 1955 Sebring Road Race.

From Student Cameras

1. **University of Cincinnati SAE Student Branch members** were recent guest of Armco Rolling Mills in Middletown, Ohio where they were treated to a three hour inspection tour.

2. **Indiana Technical College SAE Student Branch members** surround **John J. Thornton** of the Fellows Gear Shaper Co. as he explains his gear display to the group at the Fall Term Banquet which was held on Nov. 6.

The program, "Highlights of the Art of Generating and Gear Manufacturing Equipment," included a presentation of films which explained the principles of gear generation.

DETROIT

G. J. Gaudaen, Field Editor

New Rules for Ford Memorial Award

The rules of the **Henry Ford Memorial Award** have been modified to encourage wider participation in this annual contest sponsored by the **SAE Detroit Section.** No longer will the authors be restricted to engineering investigations with which they have been directly associated. Instead, a paper on any subject related to automotive ground vehicles will be eligible. This broadened scope should provide an opportunity for many more young engineers to compete for this honor.

The Henry Ford Memorial Award is open to any SAE members under 33 years of age and papers from all meetings of the Society, both Section and National will be considered by the award committee.

The new rules effective on papers presented after June 1, 1957, are stated as follows:

1. This award was established and is administered by the Detroit Section. All members of the Society of Automotive Engineers, regardless of their Section or non-Section affiliations, are eligible for the award, subject to the following rules.
2. Eligibility for the award shall be restricted to members, regardless of membership grade, who are under thirty-three years of age at the time they enter papers in the competition.
3. The award shall be made to the author of an original paper which has been presented, or is suitable for presentation to an SAE meeting. In the case of co-authored papers, both or all co-authors must comply with the same eligibility requirements as a single author.
4. The content of competing papers is limited to subjects related to automotive ground vehicles.
5. All eligible papers presented to any meeting of the SAE including its Sections, or submitted to the award committee, during the SAE Detroit Section year of June 1 to May 31, are to be considered by the award committee.
6. In any one year, when the excellence of more than one paper justifies it, the award committee may designate a "second order of merit." A paper so designated is eligible to compete for the award in the next succeeding year.
7. Three years must elapse after receiving the award before the same author is again eligible for competition.

From Section Cameras

1. "The Design and Development of Aluminum Engines" was the subject discussed by **James M. Smith,** head of the automotive engineering section, Aluminum Co. of America at the Nov. 26 meeting of the **South Texas Group.**

2. Featured speaker at the Nov. 5 meeting of the **Mid-Michigan Section** was **Lt. E. D. Mulcahy,** who based his remarks on an article entitled "Sea-Borne Deterrent" by George Fielding Eliot as taken from the U. S. Naval Institute Proceedings.

3. **Mohawk-Hudson Section Chairman L. F. Smith** (left) welcomes **George W. Gibson, Jr.,** (center), assistant chief engineer of car operations, Dodge Division, Chrysler Corp., to the Dec. 6 meeting, while **Harold Craig,** Section past-chairman looks on. Gibson's topic was "Automobile Design and Public Preference."

4. The effects of heat ranges in spark plug operation on engine performance were vividly described by **A. A. Weinberg,** service engineer, Champion Spark Plug Co., at **Northern California Section's** November meeting.

5. Following speaker Weinberg's talk, **Frederick Agabashian,** also of Champion Spark Plug Co., used a Champion test engine to demonstrate his talk on automotive developments on and off the racetrack.

6. Preceding the discussion, **E. Roger Burley** was presented an award honoring his 35 years of membership in SAE. Plaques commemorating 25 years of service to the Society were also presented to **W. H. Sievert** and **C. H. Yackey.**

From Section Cameras

1. **K. L. Campbell,** manager of truck tire engineering, Forestone Tire & Rubber Co., predicts "Trends in Tire Design" at the Nov. 14 meeting of the **Twin City Section.**

2. At the same meeting **F. W. Anderson** (right), president, Northwestern Motor Co., receives a plaque honoring his 35 years of membership in SAE from **D. D. Hornbeck** (left), Section vice-chairman. **Norman Ness,** standards engineer, Minneapolis-Moline Co., was also honored with a plaque, in absentia, for his 25 years membership in the Society.

3. **Frank P. Gross, Jr.,** new member of SAE in the Texas Gulf Coast Section, receives a membership pin from **W. B. Tilden,** Section secretary, at the Nov. 9 meeting. Others at the table from left to right are: **R. F. Wilson,** Section vice-chairman; **Donald Wing,** technical chairman for the meeting; **D. H. Carson,** Goodyear Tire and Rubber Co., who discussed "The Technical Aspects of the Tubeless Tire Story"; and **O. H. Steiter,** Section Meetings chairman.

4. Honored guest at **Oregon Section's** annual banquet and inauguration of officers dinner, held on Nov. 10, gather for a "not so formal" Journal photograph. Left to right are: **Elmer Sowers,** Section secretary; **Julius Gaussoin,** master of ceremonies; **E. W. Rentz, Jr.,** manager, SAE Western Branch Office; **Edward Werlein,** Section chairman; **Chester Hancock,** Section vice-chairman; and **Victor L. Brandt,** Section treasurer.

5. Seated at the speakers' table for the Dec. 6 meeting of the **Twin City Section** are left to right: **Thomas E. Murphy,** Placement and Student chairman; **Charles A. Amann,** research staff, gas turbine department, General Motors Technical Center, General Motors Corp., who spoke on "Regenerative Whirlfire Engine for Firebird II"; and **S. H. Knight,** Section chairman.

Murphy is a professor at the University of Minnesota and Amann is a former student of Professor Murphy. In his talk Amann mentioned that his former professor's encouragement in thermodynamics resulted in his interest of the gas turbine.

ALBERTA

L. A. Dulmadge, Field Editor

Highlight of the Nov. 19 meeting of the Alberta Group's program was a talk on "Torsion Bar Suspension" by **Gerald C. Wates,** district service representative for Studebaker-Packard Corp.

Section Meetings

ATLANTA
February 4 . . . **Jerome Lederer,** managing director, Flight Safety Foundation, New York. — "Airplane Safety Research." Dinner 6:30 p.m. Meeting 8:00 p.m.

CENTRAL ILLINOIS
January 28 . . . **B. Pinkel,** NACA —"Aircraft Crash Research." Pere Marquette Hotel. Dinner 6:30 p.m. Meeting 7:45 p.m. Special Features: Coffee Speaker.

CLEVELAND
January 21 . . . **C. H. Nystrom,** American Bosch Arma Corp.— "Fuel Injection for Automobiles." Lake Shore Hotel. Dinner 6:30 p.m. Meeting 7:45 p.m. Special Features: **Chester Lauck,** who was Lum of Lum & Abner will be coffee speaker.

CHICAGO
February 12 . . . **Jules Laegeler,** manager product improvement, department, Frank G. Hough Co., Libertyville, Ill.—"Model 12 Payloader." Grand Ballroom, Hotel Knickerbocker. Dinner 6:45 p.m. Meeting 8:00 p.m. Special Features: Social Half-Hour 6:15 to 6:45 p.m., sponsored jointly by Frank G. Hough Co., Borg & Beck Division, Borg - Warner Corp., and Pesco Products Division, Borg-Warner Corp.

CHICAGO—South Bend Division
January 28 . . . **D. Firth,** vice president, engineering, Dodge Mfg. Corp., and **J. Chung,** chief development engineer, Dodge Mfg. Corp., Mishawaka, Ind.— "Flexidyne." Bronzewood Room, LaSalle Hotel, South Bend. Dinner 6:45 p.m. Meeting 8:00 p.m. Special Features: Joint meeting with St. Joseph Valley Chapter, ASME.

COLORADO
January 17 . . . Speaker from Glenn L. Martin Co., Denver. General Motors Training Center. Dinner 6:30 p.m. Meeting 8:00 p.m.

DETROIT
January 28 . . . Junior Group Meeting—Three Speakers: **L. M. Wallace,** Chrysler Corp., **R. E. Denzer,** Chevrolet Motor Division, GMC and **D. H. Iacovoni,** Ford Motor Co. — "Tomorrow's Dream Car Ride . . . ?" Moderator: **H. P. Freers,** Mercury Division, Ford Motor Co. Small Auditorium, Rackham Educational Memorial. Meeting 8:00 p.m.

METROPOLITAN
January 17 . . . Aeronautic Activity Meeting. **R. E. Ledbetter,** General Electric Co.—"Jet Engine Controls." Garden City Hotel, Garden City, L. I. Meeting 7:45 p.m.
January 24 . . . Fuels & Lubricants Activity Meeting. Esso Research & Engineering Labs., Linden, N. J. **J. L. Philips** and **N. H. Rickles,** Esso Research & Engineering Labs.—"Residual Fuels in Diesels." Tour of Laboratories 5:00 p.m. to 6:30 p.m. Dinner 6:30 p.m. $2.00 per person. Meeting 7:45 p.m.

MID-MICHIGAN
February 4 . . . **Dr. Darrel Romick,** project staff engineer, Goodyear Aircraft Corp., Akron. —"The Conquest of Space." Bancroft Hotel, Saginaw. Dinner 6:30 p.m. Meeting 8:00 p.m.

MILWAUKEE
February 1 . . . **John F. Adamson,** assistant to director of engineering, American Motors Corp., Kenosha, Wisc. — "The New American Motors V-8 Engines." Milwaukee Athletic Club. Social Hour 6:00 p.m. Dinner 6:30 p.m. Meeting 8:00 p.m. Special Features: "Get Acquainted" mixer following the meeting.
February 8-15-22 . . . March 8–15. Fifth Annual Lecture Series. — "Engineering Know-How in Engine Design." Marquette University, Milwaukee.

MONTREAL
January 21 . . . Students' Night. Competitive Papers. One student each from McGill University and Ecole Polytechnique Institute. Prizes $50.00 and $30.00. Mount Royal Hotel. Dinner 7:00 p.m. Meeting 7:45 p.m.

NORTHWEST
January 18 . . . **R. E. Norris,** fleet & special representative, Purolator Products, Inc., Rahway, N. J.—What's New in Air Filters?" Stewart Hotel. Dinner 7:00 p.m. Meeting 8:00 p.m.

OREGON
January 16 . . . **Edward J. Masi,** service sales representative, American Bosch Division, American Bosch Arma Corp., San Francisco, Calif.—"Bosch Gasoline Injection." Imperial Hotel. Dinner 7:00 p.m.

ST. LOUIS
January 31 . . . **J. S. Coleman** and **W. A. Turunen,** General Motors Technical Center.—"Automotive Gas Turbines." Congress Hotel. Dinner 7:00 p.m. Meeting 7:45 p.m.

SOUTHERN CALIFORNIA
January 14 . . . Truck & Bus Meeting. **John B. Burnell,** assistant staff engineer in charge of engine design, Chevrolet Division of GMC, Detroit.—"The General Motors Fuel Injection System." Rodger Young Auditorium. Dinner 6:30 p.m.

SOUTHERN NEW ENGLAND
February 5 . . . **Dr. H. H. Haas,** chief engineer, Diesel Section, Continental Aviation & Engineering Corp., Detroit.—"From Spark Ignition to Diesel." Hotel Shelton, Springfield. Dinner 6:45 p.m. Meeting 8:00 p.m.

WASHINGTON
January 15 . . . **Carl Harry Nystrom,** American Bosch Arma Corp., Springfield, Mass.—"Automotive Gasoline Injection Systems." Occidental Restaurant, Washington, D. C. Dinner 7:00 p.m. Meeting 8:00 p.m.

WESTERN MICHIGAN
February 5 . . . **Walter Isley,** ordnance project engineer, Continental Motors Corp., Detroit.— "Adapting Fuel Injection to Current Engines." Doo Drop Inn, Muskegon, Mich. Dinner 7:00 p.m. Meeting 8:00 p.m. Special Features: Social Period 6:30 p.m. Film.

WILLIAMSPORT
February 4 . . . **R. T. Jackson,** sales engineer, Perfect Circle Corp., Hagerstown, Ind.—"Indianapolis Race Car Design." Moose Auditorium. Dinner 6:45 p.m. Meeting 8:00 p.m.

continued from page 102

Production Forum, Oct. 11, 1955, in Los Angeles. Panel leader was W. E. Woolwine, Northrop Aircraft, Inc. Panel co-leader was W. Barker, North American Aviation, Inc. Secretary was W. R. Slagg, Northrop Aircraft, Inc. Members included: W. Ricketts, North American Aviation, Inc.; F. F. Trygg, Lockheed Aircraft Corp.; H. Williams, Convair Division, General Dynamics Corp.; D. M .Voss, Douglas Aircraft Co., Inc.; C. R. Andrews, Douglas Aircraft Co., Inc.)

Wanted: Aircraft Designed for Cargo

Based on paper by

R. F. STOESSEL

and

E. W. FULLER

Lockheed Aircraft Corp.

AIRFREIGHTERS in use today have evolved from aircraft designed primarily for passenger carrying. Hence their suitability for handling cargo is limited. To develop the economic potential of the cargo carrier, consideration of fundamental design is needed.

Airfreighter optimum size requires a compromise of the following conflicting factors:

1. For a given number of airplanes produced and for the same load factors, the larger craft can be expected to attain lower per ton-mile operating costs.

2. The market for truly large airfreighters may not be as great as that for the smaller types. Hence initial cost per pound of airframe for the large airplane may be higher.

3. The individual operator will need a smaller number of the large aircraft for a given fleet capability, thus increasing the spare parts investment as a percentage of initial airplane costs.

4. Where schedule frequency is important, a fleet of the larger airplanes may tend to operate at somewhat lower load factors than will the smaller and more flexible airplanes.

Range and speed are vitally important factors to be considered in arriving at design configuration. For military inter-continental operation, the range must be capable of handling the San Francisco-Honolulu run of approximately 2400 nautical miles equiv-

alent to still-air distance. And there should be a second range still-air distance of about 3500 nautical miles.

For domestic commercial service there may be another range of less than 2000 nautical miles, permitting a non-stop run from the Chicago-Detroit area to the west coast.

Speed is important. U.S. domestic shippers will probably want first-morning delivery of their products, or first-afternoon followed by second-morning deliveries. Assuming departures no earlier than 11:00 p.m., this will set cruising speeds.

Since operating cost is largely a per hour cost, an increase in speed tends to reduce the cost per mile or per ton-mile. However, speed increases have offsetting penalties.

There are many unresolved cargo handling considerations. Some reflect personal preference. Here are just a few questions that will have to be answered:

1. Should modular loading be considered?

2. Should the cargo compartment be pressurized?

3. If wall and ceiling tie-downs are considered, should they be designed for incorporation of a single crash-resistant barrier and/or multiple type of diaphragm barrier?

4. What is the goal for minimum time at en route stops and at turnaround?

(Paper "Airfreighter Suitability" was presented at SAE National Aeronautic Meeting, New York, April 1956. It is available in full, in multilith form, from SAE Special Publication Department, 485 Lexington Ave., New York 17, N.Y. Price: 35¢ to members; 60¢ to nonmembers.)

Dart Turboprop Steps Up Performance

Based on paper by

C. M. RICE

Westinghouse Aviation Gas Turbine Division

THE Dart turboprop engine, which has been in service, has a rating of 1545 equivalent shp and a specific fuel consumption of 0.75 lb/hr/esph. Through redesign and improvement of component efficiencies the rating is being increased progressively.

The RDa-6 model will have a take-off rating of 1695 eshp and a 0.705 lb/hr/eshp specific fuel consumption. Basic changes in this model are: a new reduction gear incorporating double-helical pinion gears and wider teeth, and improved tip seals on the turbine blades.

The Model RDa-7 under development will be rated at 1850 shp (2000 eshp) and have a specific fuel consumption of 0.66 lb/hr/shp. This take-off rating meets the requirements of medium-sized transports operating between major cities. The increase in rating is being accomplished by: (1) shrouded impellers, incorporating seals on the shroud and (2) an additional stage on the turbine.

The growth potential of the Dart engine from a technical viewpoint is very promising. A turbine inlet temperature increase of 50 C will mean an increase of take-off hp to 2020 shp with a reduction in specific fuel consumption to 0.64 lb/hr/shp. Very little mechanical change in the engine is anticipated since the RDa-7 will be built with the major features to accommodate the increased temperature. The increase in power at the maximum continuous and cruise condition operation

from the increase of 50 C in turbine inlet temperature also can be doubled by a relatively small increase in rpm. When these increased rpm developments have been proven in the growth engine, they can be applied immediately to the original RDa-7 with a 10% increase in the maximum continuous and cruise hp currently estimated. This means an increase in recommended cruise power at 20,000 ft and 300 knots from 1090 to 1265 hp. The application of turbine blade cooling should permit a further temperature increase of at least 50 C with another 10% in power and another 3% reduction in specific fuel consumption.

Available compressor data shows that it is possible to develop the Dart engine to 2500 shp for take-off with a specific fuel consumption of 0.60 lb/hp/shp. By increasing the airflow capacity by 10% a take-off rating of 2750 shp is possible without changes to the basic diameter of the engine. (Paper "The Dart Turboprop Engine" was presented at SAE South Bend Section Meeting, January 1955. It is available in full, in multilith form, from SAE Special Publications Department, 485 Lexington Ave., New York 17, N. Y. Price: 35¢ to members; 60¢ to nonmembers.)

Five-Minute Ride Still Best Noise Test

Based on paper by

D. R. WHITNEY

General Motors Corp.

IN most sound work the sound level meter is very useful. But it is of little value in the automotive field because there are so many sources of excitation and human psychology plays such an important role in car noise evaluation.

In many respects the tape recorder can provide a less biased comparison of noises on the basis of noise alone than any other system of evaluation. But the tape recorder-jury method of noise comparison fails to take into account many of the psychological factors which do affect customer rating of a car.

Unfortunately, there is no single instrument or group of instruments which can be substituted for the human evaluation of noise, so we will continue to be plagued with the five-minute ride as a measure of progress in our business. (Paper "Unmeasurable Factors of Passenger Car Noise" was presented at SAE Passenger Car, Body and Materials Meeting, Detroit, March 1956. It is available in full, in multilith form, from SAE Special Publications Department, 485 Lexington Ave., New York 17, N. Y. Price: 35¢ to members, 60¢ to nonmembers.)

Seek Mechanism Of Surface Ignition

Based on paper by

DONN B. WIMMER

Phillips Petroleum Co.

STUDY of factors influencing the occurrence of deposit-induced surface ignition, particularly the role of deposit temperature and mechanism of deposit heating, reveal that:

- A unique relationship exists between mean pellet (or deposit) temperature and the occurrence of surface ignition regardless of deposit type, fuel type, or air-fuel ratio. Variations in compression ratio shift this relation slightly but do not invalidate the conclusion that a quantity measured by mean pellet temperature determines the occurrence of surface ignition.
- Differences in the tendencies of various fuels to undergo surface ignition arise from their varying ability to undergo surface combustion and not from any significant variation in their "inherent resistance" to surface ignition.
- Differences in the abilities of the various deposit materials to induce surface ignition arise from differing abilities to support surface combustion and undergo deposit combustion.
- Conditions probably exist where heat transfer from combustion chamber gases can heat thermally isolated deposit flakes to temperatures sufficiently high to cause surface ignition. Under such conditions the problem becomes one of combustion chamber cleanliness and heat transfer factors.

(Paper "Some Factors Involved in Surface Ignition in Spark-Ignition Engines" was presented at SAE National Fuels and Lubricants Meeting, Tulsa, Okla., November 1956. It is available in full, in multilith form, from SAE Special Publications Department, 485 Lexington Ave., New York 17, N.Y. Price: 35¢ to members, 60¢ to nonmembers.)

Trucks and Earthmovers Turn To Torqmatic Drives

Based on paper by

H. C. KIRTLAND

and

R. M. SCHAEFER

General Motors Corp.

MORE and more trucks and earthmoving equipment are being supplied with torque-converter drives. Manufacturers have initiated this trend by building the transmission to meet the specialized needs of these equipments. Three types of torque converters are now available to meet these diverse applications—each with specifically different characteristics:

1. **For tractors, loaders, and rubber-tired prime movers**
   - equal number of speeds forward and reverse
   - ratio steps of about 2:1 with three speeds
   - sensitive shift
2. **For dump trucks, scrapers, and off-highway vehicles**
   - 4 speeds forward and 1 or 2 reverse.
   - ratio steps that produce a 1-2-4-6 progressive set-up
   - optional lock-up clutch
   - optional hydraulic retarder
3. **For highway trucks**
   - 6 speeds forward and 1 reverse
   - ratio steps approximately 1.4:1 (6:1 overall coverage)
   - automatic controls
   - automatic lock-up clutch
   - optional hydraulic retarder

(Paper "What's Behind the Trend to Torqmatic Drives" was presented at SAE Central Illinois Earthmoving Industry Conference, Peoria, Ill., April 1956. It is available in full, in multilith form, from SAE Special Publications Department, 485 Lexington Ave., New York 17, N. Y. Price: 35¢ to members; 60¢ to nonmembers.)

SAE LOOKS OVERSEAS

continued from page 32

Offsetting the benefits that Great Britain's industry can obtain from these training programs is the desire of engineers and technicians to take their skills abroad, particularly to the United States where their salaries are not so limited by income tax.

In Germany there has been a radical change in training concepts. While formerly maintenance was based on the skill of craftsmen, today Lufthansa expects a mechanic to think like an engineer. Particularly where precision machinery has replaced technical skill, the emphasis is on understanding instead of craft skill. ■ END

MODERN MAINTENANCE FACILITIES

Lufthansa has built the most modern maintenance base in Europe. It is being expanded to take care of the 1649's, Viscount 800's, and Boeing 707's that have been ordered. The present facility is 722 ft long, 164 ft deep, and 48 ft high—large enough to accommodate eight planes at one time. The doors open on four tracks, either by sections or to a maximum opening of 514 ft. The entire structure is supported by three walls and one pillar, a remarkable engineering achievement.

Unlike most shops in Europe, this one is well-lighted and has a combination ceiling and floor heating system. The concrete floor contains 15 miles of hot water pipe which brings the 14-in. slab to a temperature of 77 F. This is augmented by an infrared heating system in the ceiling. All heating elements in the floor and ceiling are divided into sections so that the plant can be heated as desired. All electrical, water, and other services are placed at strategic points through the hangar in pits. Overhead there are complete sets of electric cranes, devices which are used sparingly in Europe. Adjacent to the hangar is the engine overhaul shop which employs the latest techniques, including the horizontal technique for tearing down and building up an engine. The first test cell has been completed, and it represents the synthesis of the best acoustical brains in Western Germany. An engine running at full throttle is muffled to 40 decibels outside.

SNECMA'S FLYING ATAR

The Flying Atar, SNECMA'S vertical take-off aircraft, is undergoing tethered flight tests and has just passed contractual tests calling for a complete radio-controlled flight, including take-off and landing within a 12-ft circle. Stability control is accomplished by compressed air that is bled from the compressor and led out through jets on the side. This aircraft does not have wings. The Flying Atar develops a maximum thrust of 6200 lb and weighs, with a fuel load, 5600 lb, giving a power-to-weight of 1:1. This may not appear to be much, but it is enough to get off the ground, and the point to bear in mind is that the ratio increases as the fuel load decreases. The power-to-weight ratio of the engine is 4:1, the same as that of the Rolls-Royce Conway. There is no American engine with comparable power-to-

weight ratio. Below is a tabulation of thrust-weight ratios and specific fuel consumption for representative engines:

Engine	T/W	SFC, lb/ehp-hr
Allison J71	2.5	0.80
A-S Sapphi	3.7	0.80
C-W J65	3.0	0.91
P-W J57	2.3	0.80
R.R. Ra29	3.7	0.76
R.R. Conway	4.0	0.70
Atar	4.0	0.90

The machine shops at SNECMA, which are quite extensive, have some automatic equipment; but great reliance is still placed on hand fabrication. SNECMA, uses a unique technique of mounting the whole compressor stator and casing on a machine and rotating it in order to machine the ends of the stator blades. The same technique is used for finishing the rotor.

SNECMA has a large and new test facility at Melun-Villaroche, about 30 km from Paris, with test cells, flight test facilities, and a new wind tunnel.

AT DE HAVILLAND ENGLAND

At Hatfield, de Havilland is reworking Comet 2's belonging to the RAF by removing the entire section containing the windows and replacing it with a new section having four layers of metal around the openings. Theory behind the new design of the window panels is that it would take at least 10 years of flying before a crack could develop and another 10 years before a crack could become serious.

The new series of Comets, the first of which is scheduled to fly in the third quarter of 1957, are known as the 4 and 4A. The model 4's will have a longer range than the 4A's, but the latter are designed for lower altitude and higher speed. The superior short-range performance of the 4A's is accomplished by reducing the wing span of the 4 from 115 ft to 108 ft. Comet 4A's will have a fuselage 40 in. longer than the 4's, permitting a seating capacity of 74 first class or 92 tourist. Cruising speed of the 4A's will be between 520 and 545 mph when flying at 23,500 ft. The 4A will have a high rate of climb and descent, permitting an optimum block-to-block speed on stage lengths of 500 miles or less. Capital Airlines has ordered four Comet 4's and ten Comet 4A's.

De Havilland is using a Comet 3 for test purposes. Aerodynamically it is the same as the Comet 4. When it is fitted with the RA29's Rolls-Royce engines (in place of the RA26's with which it has been flying for the past two years) it will be used for certification test flying. This Comet 3 will have detachable wing tips that will permit it to be converted to the 4A configuration.

Assembly has begun on the Comet 4, with three lines getting under way. In October 1956, the center sections of the fuselage were being joined on the first one. This aircraft is scheduled to make its first flight in the third quarter of 1957.

De Havilland is developing a successor to the Comet, the DH118. No information was available about this aircraft although it is understood BOAC has it under consideration. ■ END

New Members Qualified

These applicants qualified for admission to the Society between November 10, 1956 and December 10, 1956. Grades of membership are: (M) Member; (A) Associate; (J) Junior.

Atlanta Section

James U. E. Cowie (M), James W. Lucas (M), John L. Stoddard (M).

Baltimore Section

Lewis S. Beers (J), John Philip Hudak (J), 2nd Lt. John M. Senko (J), G. T. Willey (M).

Buffalo Section

Chester J. Brian, Jr. (J), William J. Fritton, II (M).

Canadian Section

Theron B. Finley (J), John W. Hutchinson (J), Andrew Morey Johnston (M), Peter B. Mason (M), Gordon E. McMullen (M), Alfred S. Rae (J), Donald Forbes Whitewood (J).

Central Illinois Section

Jack M. Angevine (J), Roger L. Boggs (M), Pearl L. Breon, Jr. (M), Clay L. Hutchings (J), Everett E. Sims (J), Joseph J. Wochner (J).

Chicago Section

Capt. Thomas F. Bamford (J), R. G. Baumhofer (M), Chung-tong Chang (J), Theo Davis, Jr. (J), G. Forrest Drake (M), Jerome R. Fornek (J), John H. Koerber (J), Harry R. Levey (M), Joseph F. Lewis (J), Millard A. McCorkel (A), Charles K. Pursell (M), Donald Lewis Smith (J).

Cleveland Section

Edwin L. Fort (J), Daniel W. Hoffman (J), Sanford Jaffe, (A), Wayne B. Kelley (M), William H. Moyer (M), Roy V. Norrlander (M), Walter F. Simon (M), Jerry J. Taborek (M).

Colorado Group

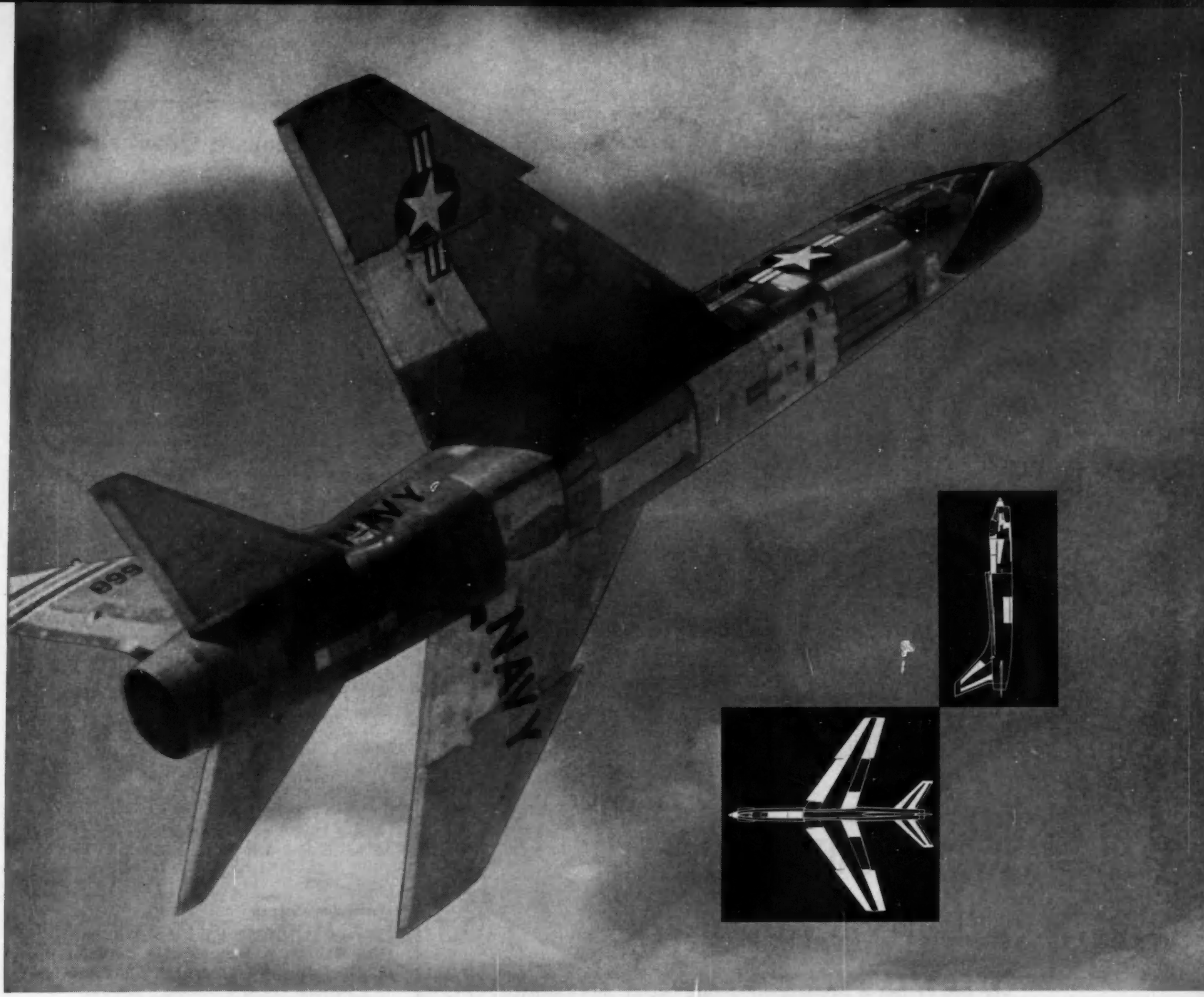
Ernest L. Teller (M), John Lee Wright (J).

Dayton Section

Robert Phil Anthes (M), Donald W. Frink, Jr. (J), Richard H. Kerr (M), David Trott Wells (J), William Olds Yeazell (M).

Detroit Section

Robert D. Aldrich (M), Charles Dudley Babb (J), David Allison Beaty (J), Charles H. Becker (A), John Belavich (J), Roger L. Berkbigler (J), Walter C. Beyer (M), Frank Borik (J), Donald W. Bullock (M), Thomas J. Burns (J), Louis V. Cachat (M), Clare L. Caswell (M), Arthur M. Christopherson (J), Jack Merlin Cudlip (A), Noel Newton Cumming (M), David W. Curry (J), Robert Alan Dent (J), Joseph L. Dodd (M), Myron Dunn (J), Kingston B. Ellis (M), Ralph C. Emig, Jr. (M), Matthias J. Esser (A), Suey Gene Y. Fong (J), Lt. Charles W. Frederick, Jr. (J), Stuart M. Frey (M), Leonard E. Froslie (M), Nilo Fuciarelli (M), Gerhard O. Gassdorf (J), Peter W. Gerstmann (M), Harvey L. Gilchrist (A), Marcus G. "Mickey" Golden (A), Richard J. Gould (M), Clayton E. Hallickson (M), William R. Haney, Jr. (J), George C. Hargraves (M), Dale Darwin Haskin (J), Robert M. Hodgson (A), Jack W. Hooper (A), Donald G. Hubbard (J), William A. Hunko (M), Richard L. Kessler (J), John J. Lenosky (M), Po-Lung Liang (M), Bernard Lis (J), James John MacKay (M), Michael Marinetti (J), Manford



Weight-saving magnesium sheet (white areas) is used for leading edges, empennage, wheel doors and many other parts of F8U-1 Crusader.

New Members Qualified

Continued

E. Mason (M), Richard W. Mattson (M), Paul E. Milott, Jr. (J), James Nagy (J), Edwin E. Nelson (J), David James O'Leary (A), Robert A. Rasmussen (J), D. F. Roth (J), Vincent Rotole (M), Richard E. Rutz (A), James F. Scharfenberg (A), James J. Schultz, Jr. (J), George B. Seifried (J), H. Marvin Smith (J), J. Kevin Smith (J), Miles B. Spickler (A), Boris George Stasuk (J), Allen Stretlien (J), J. Wilbur Tatter (M), Hiram P. Vrooman, Jr. (J), James R. Wickham (M), Edmund Wieczkowski (A), Walter T. Woloshyn (M).

Hawaii Section

Anthony A. Arruda (A).

Indiana Section

John Everett Buskirk (M), William J. Everett, Jr. (J), John I. Firth, Jr. (M), Roger W. Gallagher (J), Herman Joseph Maurer (M), Robert F. Risku (J), Donald E. Schmidt (M), Ray Donald Steward (M).

Kansas City Section

Dale P. Wire (J), John W. Wyatt, Jr. (J).

Metropolitan Section

Everett J. Adler (J), Henry Albert (M), William A. Burnett (M), William K. Detweiler (M), Bernard Diamond (J), Jerome Oscar Feldman (M), Raymond C. Kropp (A), Robert Kutrieb (J), Bramwell R. Linden (M), Maurice Paleschuck (J), Carl R. Piserchia (J), Joseph Pohrebnoy (A), Andre Peter Sampou (J), Joseph C. Scopinich (J), Arthur B. Stanley (A), Otto Wm. Vathke (J), Richard S. Wolff (M), Frank Wrobleski (J).

Mid-Continent Section

Joseph E. Morrow (M), Herbert E. Salter (M), Lawrence H. Sluder (J), Jack L. Stout (J).

Mid-Michigan Section

Gerald Case (M), Reigh C. Gunderson (J), Ward D. Miller (M), Robert J. Richards (M).

Milwaukee Section

Raymond C. Benz (J), Robert F. Bierman (A), Robert Couchman, Jr. (M), William Lawrence Denniston (M), Herbert Geissler (J), Herbert F. Haubrich (M), Lynn M. Myers (J).

Now—Cleveland provides a single source for all your socket screw requirements

Simplifies specification, cuts paper work, speeds delivery

CLEVELAND STANDARD SOCKET SCREW PRODUCTS
UNIFIED THREADS—CLASS 3A FIT

Type	Standard Sizes (diam.)	Material
Socket head cap screws	#0 to 1½ in. (larger sizes avail.)	Alloy steel, heat treated or Nonmagnetic 18-8 stainless
Set screws (cup, half dog, flat, cone or oval points)	#0 to 1 in. (#0-#3, cup point only)	Alloy steel, heat treated or Nonmagnetic 18-8 stainless (to ½ in., cup point only)
Flat head socket cap screws	#4 to ¾ in.	Alloy steel heat treated
Button head socket cap screws	#4 to ⅝ in.	same
Shoulder screws (stripper bolts)	¼ to ¾ in.	same
Dowel pins	⅛ to 1 in. (nominal size and .001 in. oversize for repair)	same
Pressure plugs	1/16 to 1¼ in. NPTF	same
Socket screw keys	.028 to 1 in. across flats; short or long arm	same

Cleveland has expanded its socket screw line to provide a single source for all your socket head needs.

At the same time, and in conjunction with opening its new plant, Cleveland is doubling its factory warehousing capacity. This, plus the latest materials handling equipment, will enable Cleveland distributors to get same-day shipment of your larger orders.

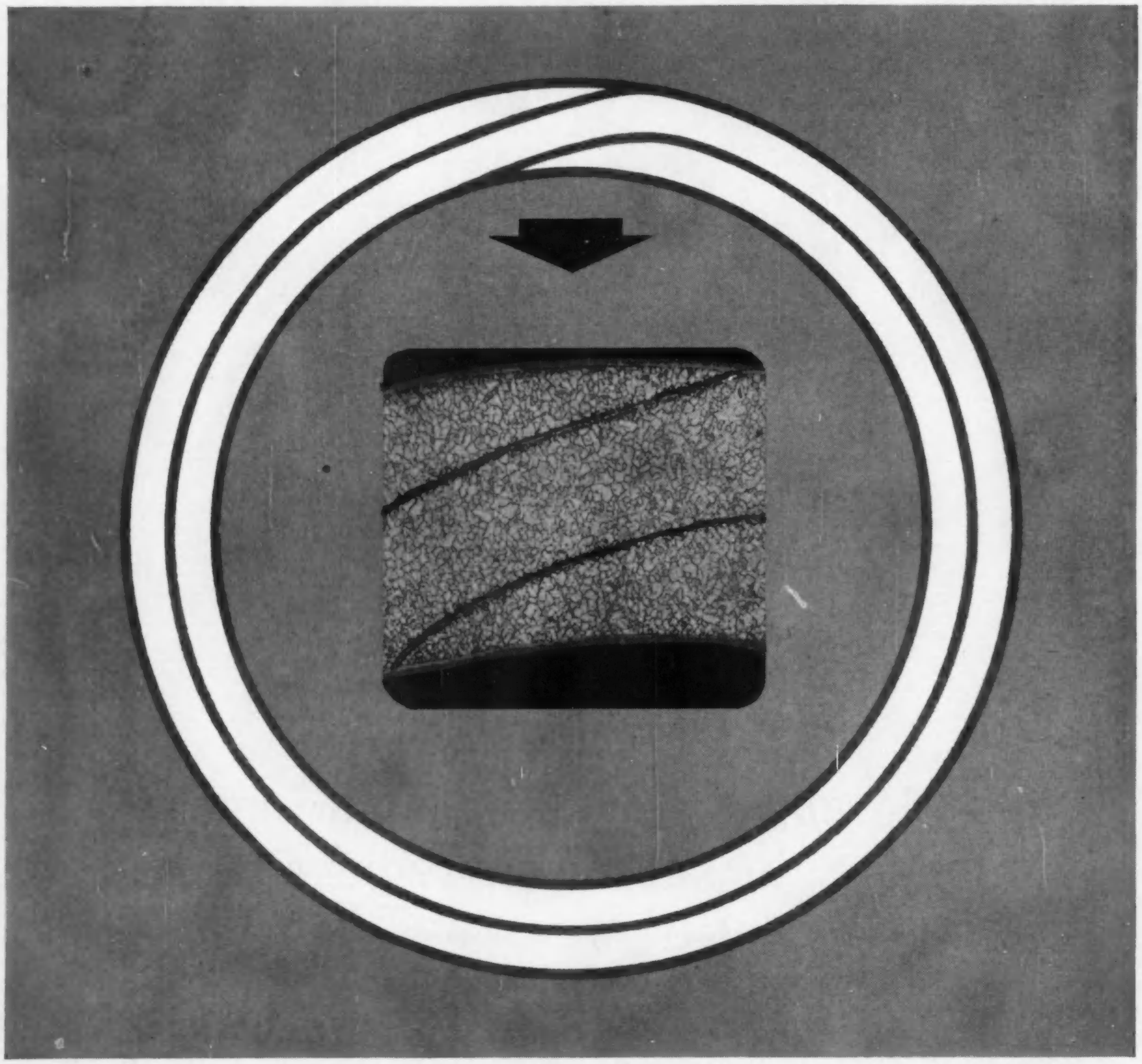
Included in the expanded Cleveland socket screw line are precision dowel pins. While not a socket head product, they are basic fasteners for the important tool and die industry, where they are closely associated with socket head cap screws and shoulder screws. We offer them as part of a complete service.

Cleveland socket head cap screws are upset forged from heat-treated alloy steel. This results in symmetrical, unbroken grain structure in heads, threads and fillets—greater fatigue and tensile strength, stronger fasteners.

Write for latest literature and technical data. Then see your local Cleveland Cap Screw distributor for all your socket screw requirements.

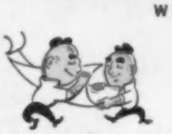
THE CLEVELAND CAP SCREW COMPANY
4444-12 Lee Road, Cleveland 28, Ohio

Only double-walled Bundyweld



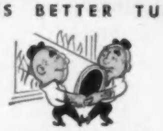
With Bundyweld's beveled edges and single close-tolerance strip, there's no inside bead at joint, as shown in photomicrograph (inset, above). The tubing is uniformly smooth, inside and out. Bundyweld fabricates easily; can be bent to shortest radii. Copper coating, inside and out, facilitates soldering and brazing operations.

WHY BUNDYWELD IS BETTER TUBING



Bundyweld starts as a single strip of copper-coated steel. Then it's . . .

continuously rolled twice around laterally into a tube of uniform thickness, and



passed through a furnace. Copper coating fuses with steel. Result . . .

Bundyweld, double-walled and brazed through 360° of wall contact.

←

NOTE the exclusive Bundy-developed beveled edges, which afford a smoother joint, absence of bead, and less chance for any leakage.

Steel Tubing meets every automotive fabrication test!

Bundy alone brings you a *double-walled* steel tubing made from a *single* metal strip—for the utmost in strength, durability, and leakproof performance

Automotive engineers have long relied on tough, leakproof Bundyweld Tubing for oil, fuel, and hydraulic lines in cars, trucks, buses, and tractors. Double-walled Bundy® Tubing's extra-sturdy construction and ease of fabrication have led to its use in an ever-increasing number of automotive applications.

Bundyweld is used in 95% of today's cars, in an average of 20 applications each.

This didn't just happen; there are two very good reasons for Bundy's overwhelming leadership in the automotive tubing field. . .

The tubing itself: Bundyweld is the only tubing double-walled from a single metal strip, with exclusive Bundy-developed beveled edges. SAE 1010 steel is copper-bonded throughout 360° of wall contact into a strong, lightweight, beadless tubing. Wall thickness and concentricity are accurate, uniform. Ultimate yield strength, tensile strength, and fatigue limit are exceptionally high.

Bundy's plus service: Bundy backs up its unique Bundyweld Tubing with a staff of engineering experts who take pride in helping solve tricky tubing problems, with unexcelled fabrication services, with custom-packaging of orders, and fast, *on-schedule* deliveries.

For more information, or help with your special tubing problems, call, write, or wire us today!

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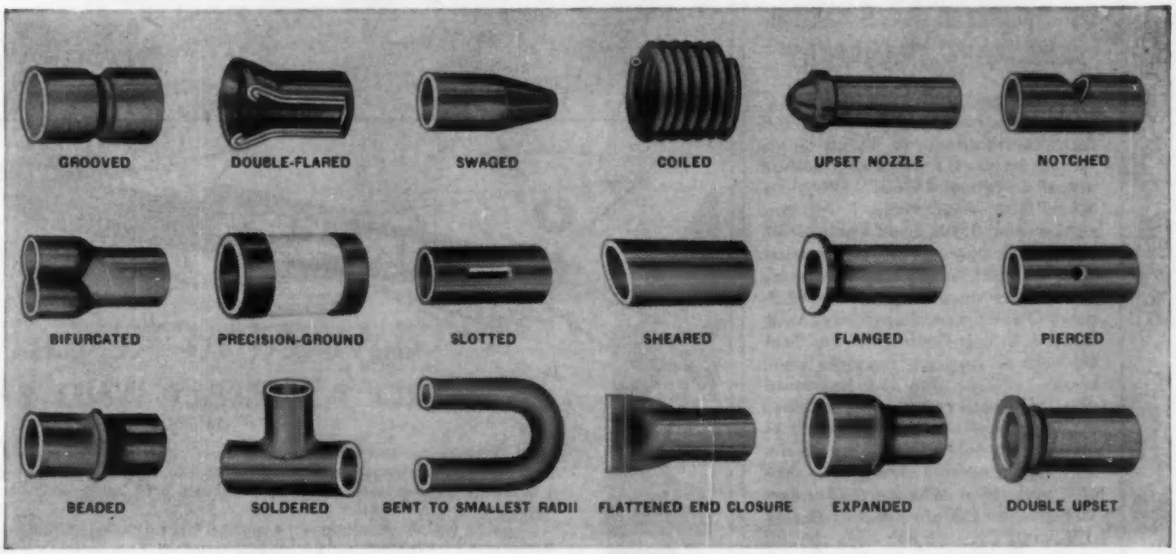

Shown above are but a few of the fabrication operations which are possible with Bundyweld Steel Tubing. Many of these, and others not shown, were developed through solving a specific problem brought to us by a customer or prospect. At any stage in the development of your product, Bundy invites you to take advantage of this design service.

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New Members Qualified

Continued

Mohawk-Hudson Section

Charles H. Anderson (M).

Montreal Section

Orest Cochkanoff (M), Bernard Lanctot (J).

New England Section

Leopold B. Blum, III (J), Edward Joseph Smith (A), George Sorkin (A).

Northern California Section

Robert C. Cuffel (M), C. Lyle Cummins, Jr. (J), Peter H. Hertel (A), James R. Mondt (J), Richard L. Reiley (J), Herbert M. Schick (M).

Northwest Section

Alfred L. Oppie (J), Calvin W. Townsend, Jr. (J).

Philadelphia Section

Lewis J. DeVuono (A), Alfred M. Di Bartolo (M), Charles B. Hood, Jr. (J), W. A. Pavlo (M), Robert S. Potteiger (J), Marshall C. Pritzbur (A), Eugene D. Tarris (J), F. Clark Walton (J).

Pittsburgh Section

James G. Berry, Jr. (J), Peter Hans Donath (J), Alan A. Glaser (J), F. Richardz (M), William P. Rowles (A), W. W. Wentz (M).

St. Louis Section

Samuel A. Gulotta (J).

San Diego Section

Clayton Wilbur Vickland (J), Edward A. White (A), John Q. A. Wickham (M).

South Texas Group

Robert J. Burkholder, Jr. (J), Andrew J. Freund (J).

New Members Qualified

Continued

Southern California Section

George F. Anisman (M), Richard B. Ault (M), Robert H. Bean (J), Frank Breckenridge (M), Charles C. Busenkell (M), Anthony P. Casagrande (J), Roland B. Clark (J), Martin L. Close (A), John R. Feemster (J), Herbert W. Fenske, Jr. (J), Robert B. Glassco (M), Alexander B. Hepler, Jr. (J), Albert M. Hetzel (J), Jack B. Hochadel (J), Louis L. LeBrun, Jr. (J), Robert Allen Lehman (J), Frank R. Mastroly, Jr. (J), C. T. Molloy (M), Rolland Moody (J), Marshall W. Novick (J), David O. Park (J), John Phinos (M), Victor E. Rimsha (M), Francis J. Schoelen (J), Patrick G. Stone (J), Robert S. Welther (J), Keith A. Wilhelm (M).

Southern New England Section

Jerome Belsky (M), Thomas E. Doherty (M), Walter D. France (M), James B. Funk, Jr. (M), Rudolph Hohenberg (J), Wayne R. Lundberg (J), Wayne MacKown (M), Orlo A. Powell, Jr. (J).

Texas Section

Glenn S. Beidler (J), David L. Kors (J).

Twin City Section

Kenneth F. Burke (M), Chester F. Lenik (M), Harry B. Silverman (J).

Washington Section

2nd Lt. Frank Allgaier (J), Lt. Col. Mario Matacotta (M).

Williamsport Group

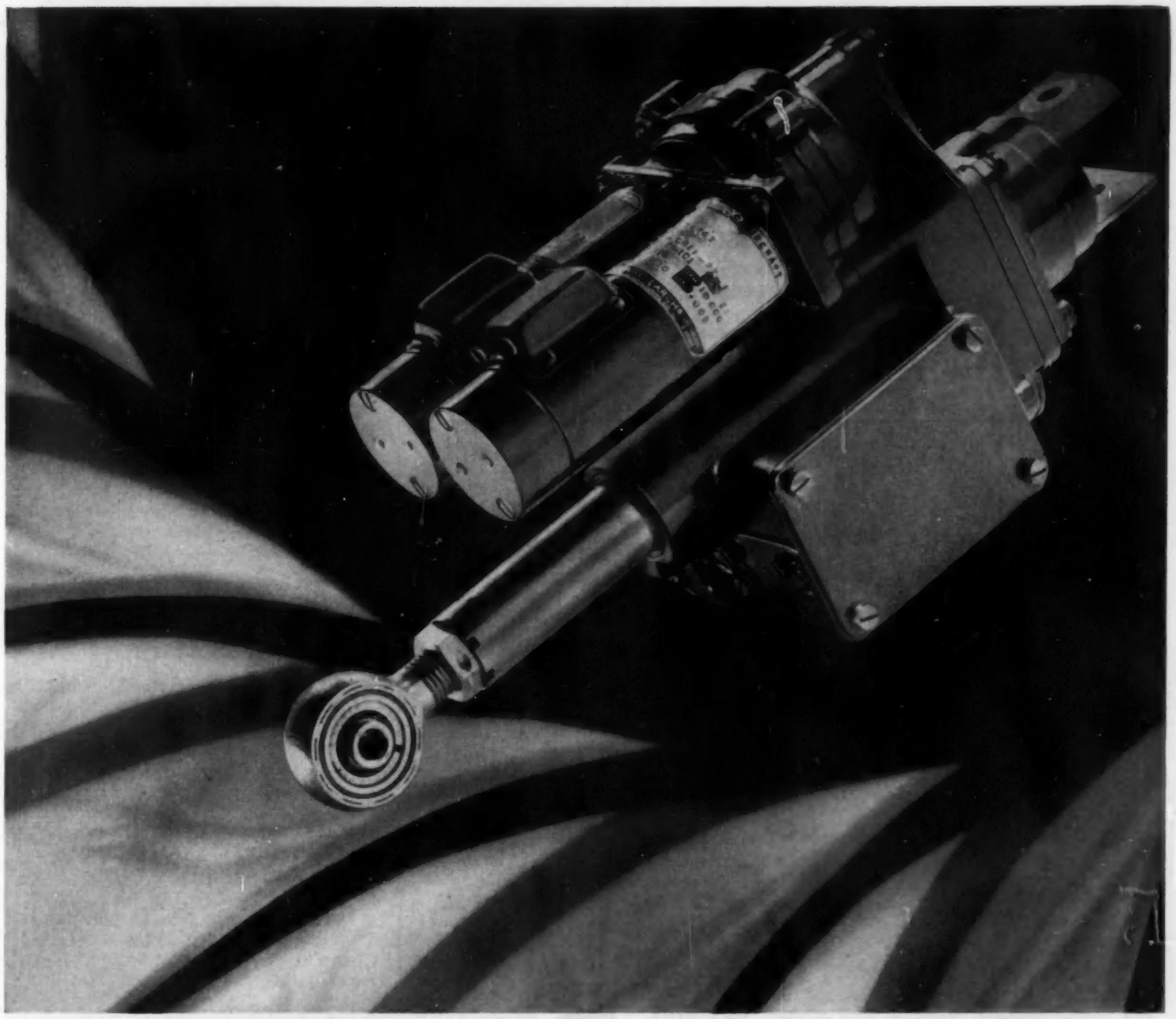
Robert L. McCumber (M).

Outside Section Territory

Wade Allen (M), William G. Beiderman (A), Harold E. Fuerst (M), Allen D. Lodge (M), George P. Nelson (M), John W. F. Petch (J), Donald H. Roach (A), Charles A. Ropes, Jr. (J), Hans Albrecht Sack (J), Raphael D. Schilz (J), William Heyl Unger (M).

Foreign

James W. Calder (J), Switzerland; S. H. Grylls (M), England; J. N. Gujral (A), India; Halvor Otto Karud (M), Norway; G. Udegbunem Meniru (J), Nigeria; Robert Michael Rey (M), Brazil; Norberto Uranga (J), Argentina.



Four-speed actuator

AiResearch two-motored unit provides automatic control plus an instantaneous manual override at the work end of its Air Data System

During high-speed flight, where control is so delicate it is often by trim surfaces alone, immediate response under emergency conditions is of critical importance. The actuator shown allows immediate pilot override of the automatic system without any disconnect activity or mechanical clutching device. If necessary any one of four speeds may be instantaneously selected.

The unit operates with complete dependability at ambient temperatures up to 300°F.

AiResearch actuators operate on split-field or permanent magnet DC motors, on AC servo motors or on single-phase, two-phase or three-phase AC motors. They can supply feedback signals to the control and be provided with neutral positioning and light-switches.

We are now engaged in the development of Air Data Systems of all types, assuming full system responsibility. Because we manufacture the entire system, including transducers, computers and actuators, you are assured of the utmost in system compatibility.

Outstanding opportunities for qualified engineers. Write for information.

THE GARRETT CORPORATION

AiResearch Manufacturing Divisions

Los Angeles 45, California • Phoenix, Arizona

Designers and manufacturers of aircraft systems and components: REFRIGERATION SYSTEMS • PNEUMATIC VALVES AND CONTROLS • TEMPERATURE CONTROLS CABIN AIR COMPRESSORS • TURBINE MOTORS • GAS TURBINE ENGINES • CABIN PRESSURE CONTROLS • HEAT TRANSFER EQUIPMENT • ELECTRO-MECHANICAL EQUIPMENT • ELECTRONIC COMPUTERS AND CONTROLS

Applications Received

The applications for membership received between November 10, 1956 and December 10, 1956 are listed below.

Atlanta Section
Kenneth W. Dorman.

Alberta Group
Jacob Janzen.

Baltimore Section
Charles F. Waters.

British Columbia Section
Donald A. Anderson, Jack Ballard, Alan Nisbet, Allan Frederick Noble.

Buffalo Section
Charles F. Desmond, Gilbert W. Langswager, William H. Tite, Jr.

Canadian Section
Peter Gardner Browne, John M. Delorme, Leonard F. De Santis, Elmer E. Downs, John Becher Gale, Frank R. Gerry, Alan Graham MacNab, R. G. Murley, David H. Parker, Henry Robert Warder.

Central Illinois Section
Norman Edward BeDell, Roy D. Chandler, John Robert Hawk, John A. McLain, James M. Reisel, Gene W. Short, George R. Verhage, James Henry York.

Chicago Section
George M. Bassnett, Robert W. Brooks, John B. Durant, Norman W. Felbinger, Daniel Gawne, Robert E. Kay, John E. Mazanet, Leland V. Meader, Richard B. Naylor, Richard B. Payne, John Philpott, Zarko Sekerez, Robert Moyer Smith, John Paul Szabo, Earl Allen Wagner.

Cincinnati Section
Ray F. Bonhaus, Bennette L. Heath.

Cleveland Section
Harold Gold, Warren G. Hampton, Arthur M. Jaggard, Gordon Meldrum, Richard S. Neely, Richard P. Reichold, Raymond J. Tushar.

Dayton Section
Richard Arthur Roberts, Sr., Cecil William Roe.

Detroit Section
Nevin L. Bean, Leo Joseph Berger, Jr., George Bernard, John S. Besemer, Charles A. Bienenstein, Glen L. Bowen, M. Victor Bower, John N. Bradley, W. Durand Brown, Arthur M. Clark, Ford Louis Coleman, Jr., Raymond T. Coudriet, Dale D. Douglass, Russel D. Foley, Irving V. Gosnell, Paul W. Hehr, Roger W. Holden, Carl J Jackson, John D. Jenks, Kenneth F. Koegler, John T. Kosinski, Leonard H. Mapes, Ernest G. Murray, Gordon A. Peterson, Richard H. Pickering, Norman O. Roff, Michael Rometti, Edward T. Sills, Robert L. Smith, Samuel J. Smoly, Reid K. Taube, Robert E. Valk, James D. Vaseau, Albert Haig Wilson, James W. Winship.

Hawaii Section
William Santos.

Indiana Section
Keith W. Epply, George E. Flinn.

Kansas City Section
Bill J. Bean, Donald Matthews, George M. Mierley, Sr., David B. Osborn, John N. Schlotter, John M. Smidl, Charles H. Stockdale.

Metropolitan Section
John C. Cox, Philip Henry Fryberger, Frederick R. Gruner, Thomas W. Hall,

Applications Received

Continued

II, David N. Harrison, W. Herbert Hultgren, John S. Kopper, Arthur S. MacDonald, Ward W. Minkler, Siegfried W. Speidel, George T. Stern, Donald A. Webster.

Mid-Continent Section

William O. Banks, Robert C. Curry.

Mid-Michigan Section

Frank Hayes, Jr., Alfred E. Hilgeman, William G. Martin, Jr., Leonard F. Stewart, Karl John Windberg.

Milwaukee Section

Harris Ewald, Robert A. Jones, Ralph Hansen Miller, Charles W. Modersohn, Philip E. Myers, Theodore H. Pulles, Frank C. Skelton, Jr., Robert E. Talley, James G. Williams.

Mohawk-Hudson Section

John H. DeWitt.

Montreal Section

Paul Belair, Stanley T. Ferry, Eugene Gore, George Thimens.

New England Section

J. Kenneth Baxter, Jr., Harold J. Elmendorf, Daniel Fairchild, John F. McCurdy.

Northern California Section

Robert W. Spencer.

Northwest Section

Roy A. Gregory, E. Everett Mansfield.

Oregon Section

Pete T. King, Gus Pautsch.

Pittsburgh Section

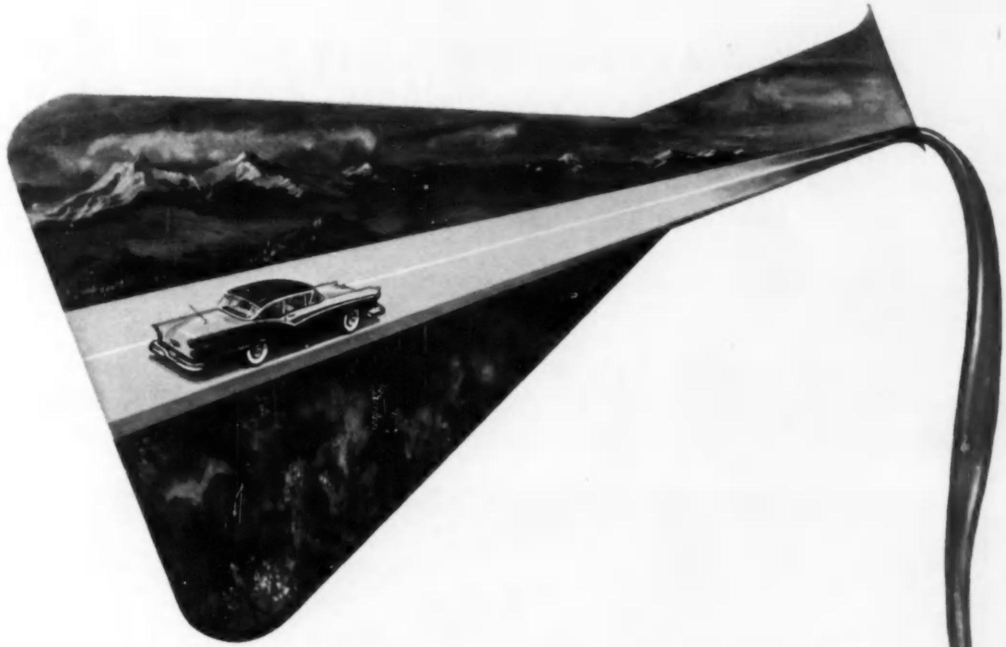
Richard W. Shiffler.

San Diego Section

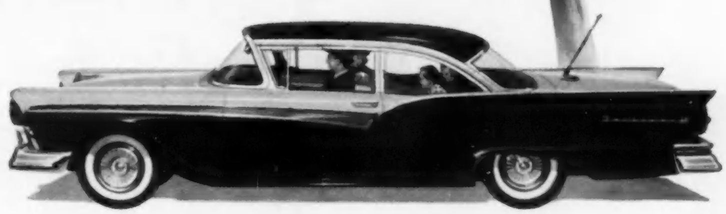
J. J. Alkazin, George W. Dinkins, Jr., Barry Lee Farrar, William L. Ihrig, Clifton E. Sadler, Noah Frederick Wessinger, Jr.

South Texas Group

William E. Doebbler, Roy D. Quillian, Jr.



How smooth riding is "poured" into your new FORD!



The "Ford in Your Future" owes a lot of its velvety ride to the DAREX "Flowed-in" GASKETS that seal its shock absorber ends.

In this use, the automatic "Flowed-in" Process takes the place of costly electric welding. DAREX machines *stream* in a special liquid sealing compound. When vulcanized, it forms a solid, rubbery seal that holds up under extreme heat and pressure . . . and helps *hold down* the bumps on the road.

Similarly, DAREX "Flowed-in" GASKETS are lowering labor and material costs and lifting product efficiency *all along the assembly line* . . . in oil and air filter covers, lamp sockets, crankcases and many other parts.

Although new in these adaptations, DAREX "Flowed-in" GASKETS have been the life's blood of the canning industry for 35 years, sealing FIFTY BILLION containers last year in the U. S. and Overseas.

Continuing research has broadened the scope of the "Flowed-in" process to important new uses in electronics and other mass-production industries, too. Maybe the complete DAREX "package" including machines, sealing compounds and localized service has a place in *your* plant.

DAREX (Flowed-in) GASKETS

THE **STREAM**-LINED SEAL OF MODERN INDUSTRY

DEWEY AND ALMY
CHEMICAL COMPANY
DIVISION OF W. R. GRACE & CO.

Cambridge 40, Massachusetts • Chicago 38, Illinois • San Leandro, California • Montreal 32, Canada

Applications Received

Continued

Southern California Section

Irving Altman, Richard Battle, Joe C. Crowley, Jr., Eric A. Davies, Joseph La Torre, Charles E. Painter, John M. Phipps, William J. Polon, William A. Ray, David C. Taylor, Philip H. Williams.

Southern New England Section

John A. Grimes, Joseph L. Magri.

Spokane-Intermountain Section

O. R. Parrish, Collin Slane.

Syracuse Section

Preston Stuart Billings, David G. Cooper.

Texas Section

Ray M. Matson, Donald Arthur Siedhof.

Texas Gulf Coast Section

Henry G. Coffman, A. S. Gardenshire.

Twin City Section

Lyle M. Jensen.

Western Michigan Section

Frank Dzielski.

Williamsport Group

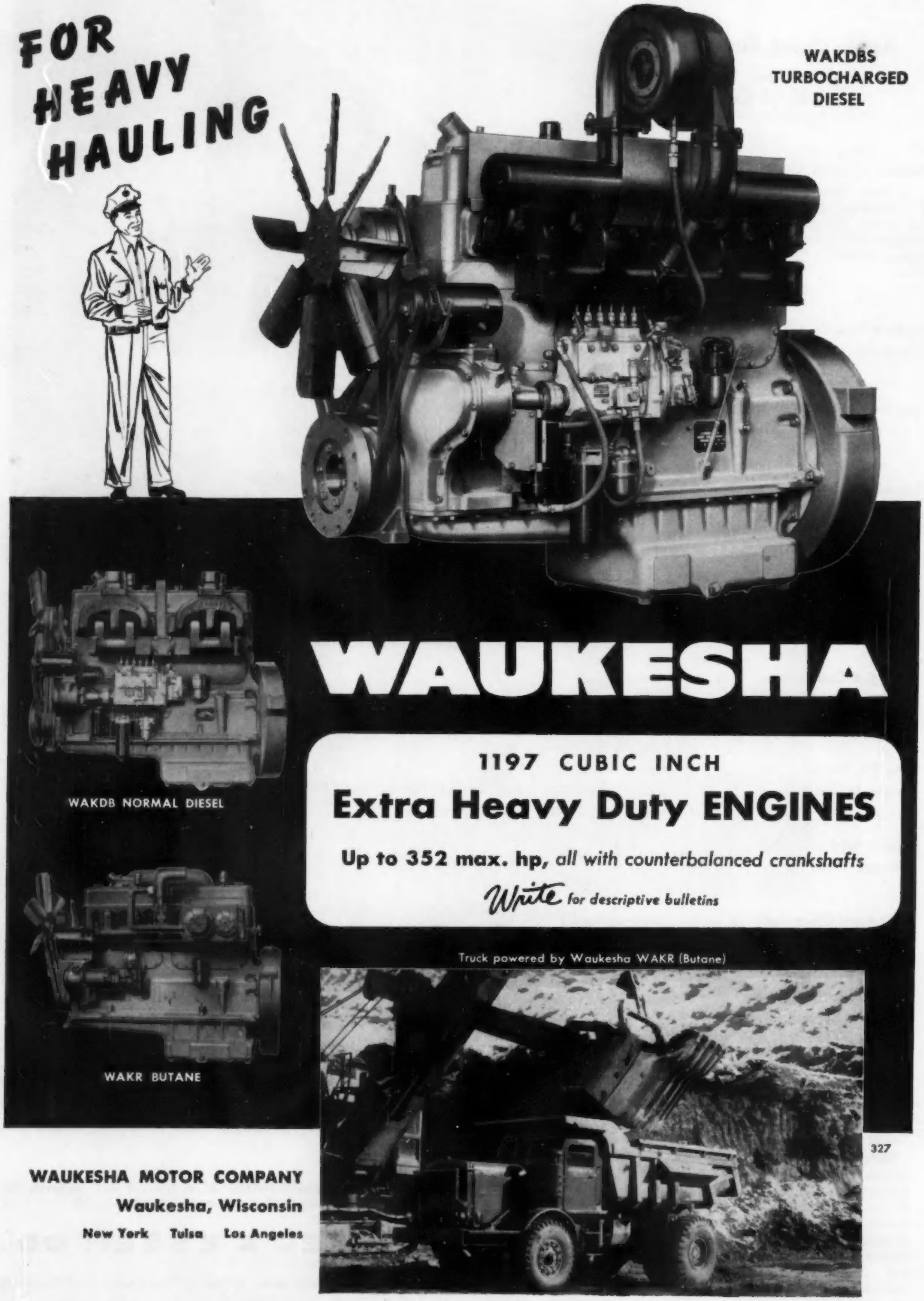
Warren R. Horak.

Outside of Section Territory

Norris E. Bacon, Paul E. Carlson, John L. French, Waldean W. Grauerholz, George E. McDonald, C. D. Stewart, Rex H. Taylor, Robert S. Temple, Wendell M. Van Syoc, Walter Vogel.

Foreign

Bernard Grindrod, Nairobi, East Africa; John J. Hoesly, Japan; Yutaka Katayama, Japan; James R. Milne, Saudi Arabia; Vincent A. Morris, South Africa; Carl Alexander Olsson, Sweden; Theodor Ries, Belgium; John Henry Sainsbury, England; Karl Ludwig Sanders, Argentina; Harumoto Sugisaka, Japan.


FOR HEAVY HAULING
WAKDBS TURBOCHARGED DIESEL
WAKDB NORMAL DIESEL
WAKR BUTANE
WAUKESHA
1197 CUBIC INCH
Extra Heavy Duty ENGINES
Up to 352 max. hp, all with counterbalanced crankshafts
Write for descriptive bulletins
Truck powered by Waukesha WAKR (Butane)
327
WAUKESHA MOTOR COMPANY
Waukesha, Wisconsin
New York Tulsa Los Angeles

R/M FLEXIBLE THIN-WALL "Teflon"* HOSE

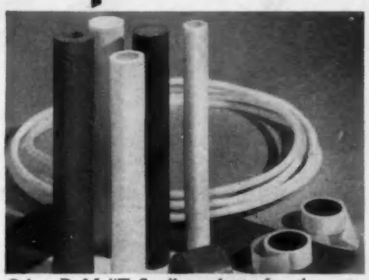
for extremes of corrosion, vibration and temperature

Corrosive fluids, high mechanical stresses, extreme ambient temperatures —R/M Flexible Thin-Wall "Teflon" Hose takes them all. It's your best assurance of high-integrity conveying lines.

This new hose—stainless steel wire-braided or rubber-covered — is extremely flexible and does not expand, contract or fatigue. It is designed for continuous operation at temperatures from −100° to +400°F, and is chemically inert to hydraulic fluids and synthetic lubricants.

This major contribution to safety and performance in the automotive and aviation industries is backed by all the resources of R/M, pioneer in the development of "Teflon" products. R/M Flexible Thin-Wall "Teflon" Hose is available through leading coupling manufacturers. A list of suppliers and complete specifications will be furnished on request.

*A Du Pont trademark



Other R/M "Teflon" products for the automotive and aviation industries include rods, sheets, tubes and tape; centerless ground rods held to very close tolerances; stress-relieved molded rods and tubes; Raylon—a mechanical grade of "Teflon," having many of the properties of virgin "Teflon." For details, call or write R/M.

RM

RAYBESTOS-MANHATTAN, INC.

PLASTIC PRODUCTS DIVISION, MANHEIM, PA.

FACTORIES: Manheim, Pa.; Bridgeport, Conn.; No. Charleston, S.C.; Passaic, N.J.; Neenah, Wis.; Crawfordsville, Ind.; Peterborough, Ontario, Canada

RAYBESTOS-MANHATTAN, INC., Engineered Plastics • Asbestos Textiles • Mechanical Packings • Industrial Rubber • Sintered Metal Products • Rubber Covered Equipment • Brake Linings
Abrasive and Diamond Wheels • Brake Blocks • Clutch Facings • Laundry Pads and Covers • Industrial Adhesives • Bowling Balls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ELECTRICAL
CONTACTS
...dependable
since 1914
FANSTEEL
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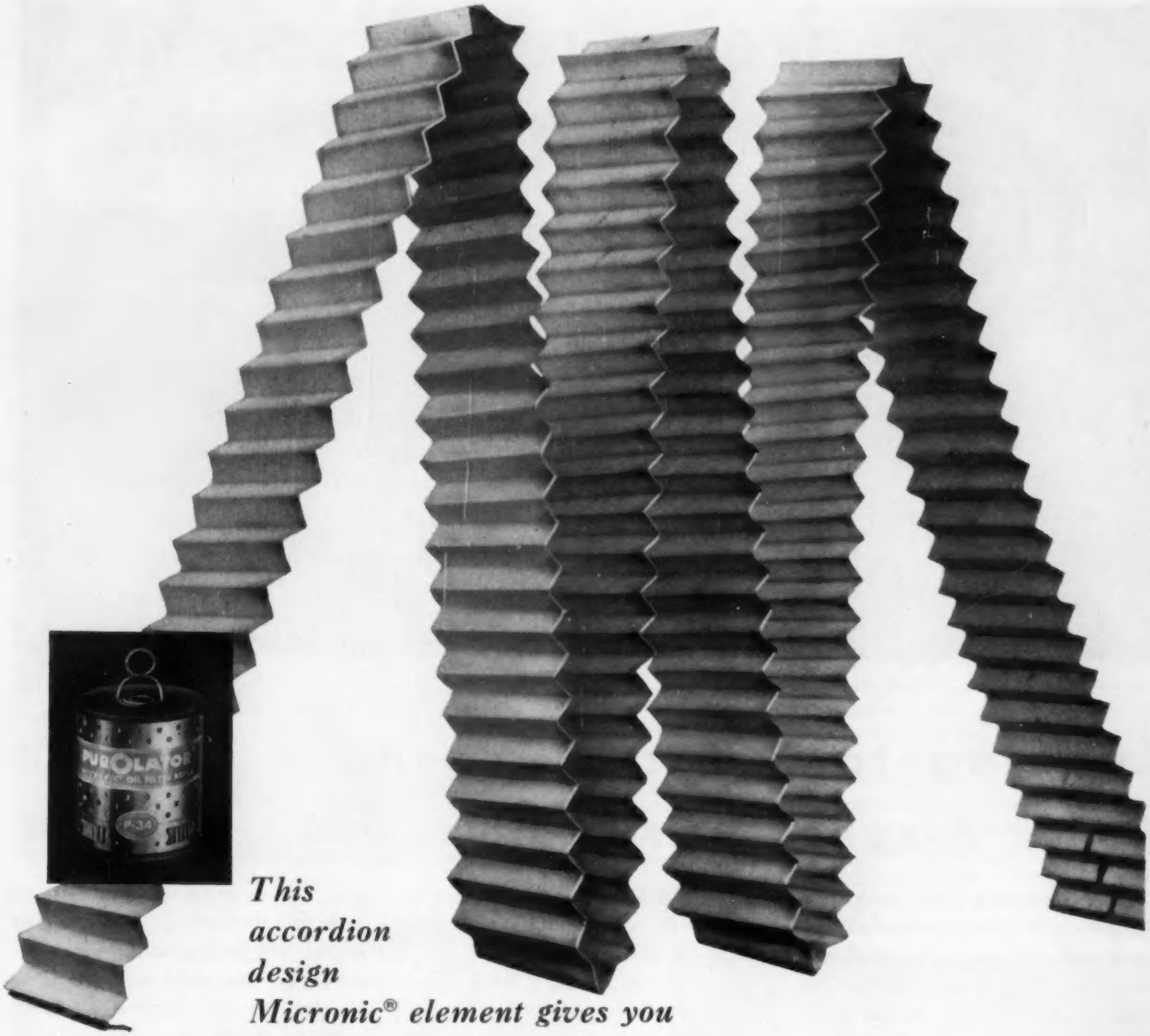
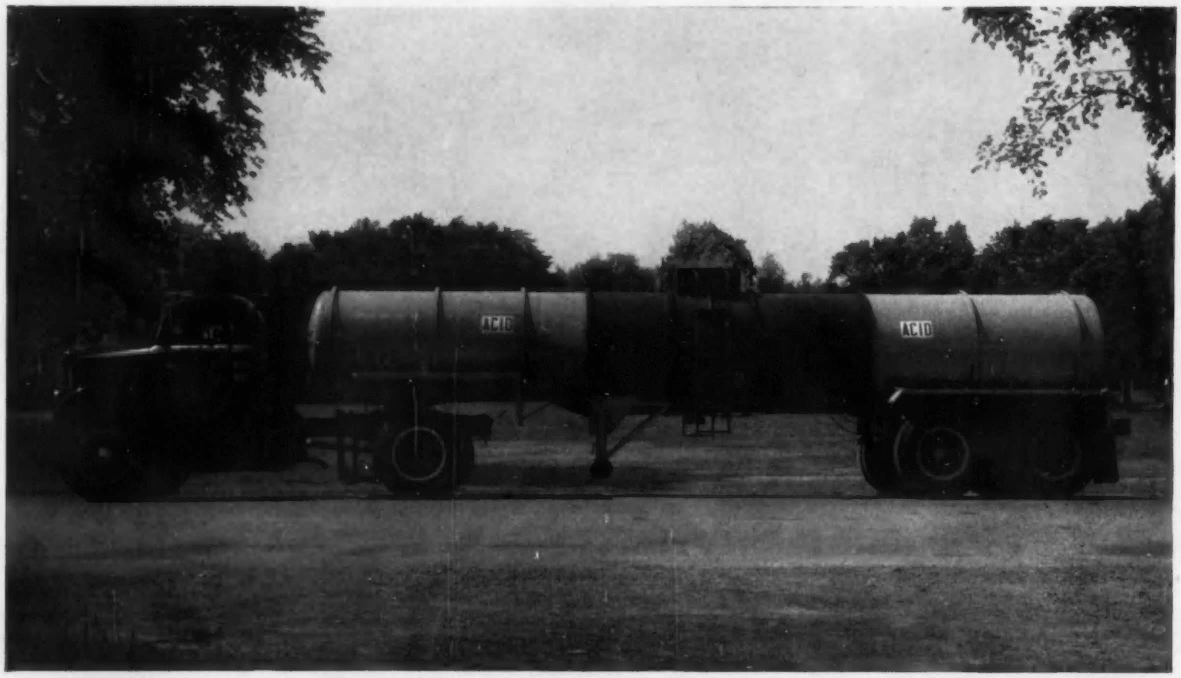
tangible, definite and usable help...
by people who are eager to give it,
able to give it!
Fansteel Metallurgical Corporation
NORTH CHICAGO, ILLINOIS, U. S. A.
F571


PUROLATOR



Leading tank carrier standardizes on Fuller 8-speed ROADRANGER® Transmissions

Fuller 8-speed, semi-automatic ROADRANGER Transmissions will be *standard* in all new tractors purchased by Leaman Transportation Corporation, Leaman Transportation Company, Inc. and Chemical Tank Lines, Inc. of Downingtown, Pennsylvania.

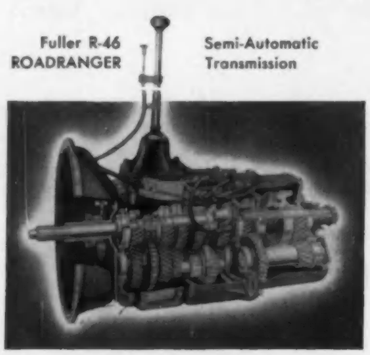
The combination of these three companies comprises one of the largest tank carrier operations in the world. Since 1930 this organization has used hundreds of Fuller Transmissions . . . and recently added 36 new R-46 ROADRANGERS in new White and International Tractors as part of the standardization on this 8-speed model.

Says D. A. (Dave) Ross, Vice President: "We get the best service from the 8-speed ROADRANGERS in our operation. Some have over 150,000 miles on them, and have not been touched. Our maintenance cost is much less . . . in fact, we haven't had any cost to date since we have had *no* trouble.

"50% of all our mileage on the petroleum hauls is with an empty trailer. With the .577 ratio in the rear axle and 10 x 22 tires, we can maintain a good road speed empty in 8th gear . . . at approximately 2000 to 2200 rpm with our gas engines. This results in better fuel mileage and better engine life. And, we are able to maintain a higher rpm at all times under a load. Our drivers now say they wouldn't have any other transmission."

For efficient, dependable operation of your trucks, ask your truck dealer now for full details on the easiest-shifting transmission available for your operation. Specify Fuller ROADRANGER Transmissions for faster trip time, lower fuel consumption, longer engine life, less driver fatigue and greater profits.

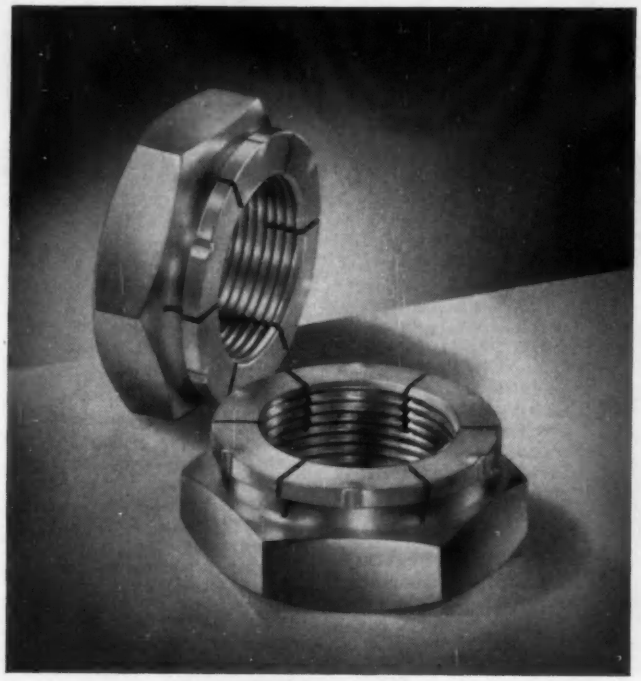
Fuller R-46 ROADRANGER — Semi-Automatic Transmission



FULLER MANUFACTURING COMPANY
Transmission Division, Kalamazoo, Michigan

Unit Drop Forge Division, Milwaukee 1, Wisconsin • Shuler Axle Company, Louisville, Kentucky (Subsidiary) • Sales & Service, All Products, Western District Branch, Oakland 6, California and Southwest District Office, Tulsa 3, Oklahoma.

Flexloc thin nuts save space, weight and production time



Self-locking nuts are 30% lower and lighter; speed up assembly with hand or power tools

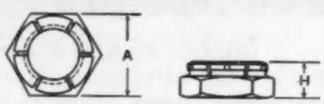
Self-locking FLEXLOC thin nuts are 30% lower than regular height locknuts of the same nominal diameter. They fit into spaces where regular height locknuts will not go. You can design lighter, more compact units with them.

Where you must reduce weight in a completed assembly, you can save by using shorter bolts with these lighter nuts. And you save production time. The length of engagement of mating threads is shorter: fewer revolutions of hand wrenches or power nut runners are needed to seat them.

FLEXLOC nuts are of 1-piece, all-metal construction. You can use a FLEXLOC fully seated as a locknut or at any point along a bolt as a stop nut. Once the threads in the resilient locking section are fully engaged, the FLEXLOC grips the mating threads with uniform locking torque wherever wrenching stops. Since there are no nonmetallic inserts to come out or deteriorate, the locking life of a FLEXLOC is virtually unlimited.

Your authorized industrial distributor stocks FLEXLOC nuts in a variety of sizes, materials and finishes. Consult him for details. Or write us for information about your special locknut problem. Flexloc Locknut Division, STANDARD PRESSED STEEL CO., Jenkintown 55, Pa.

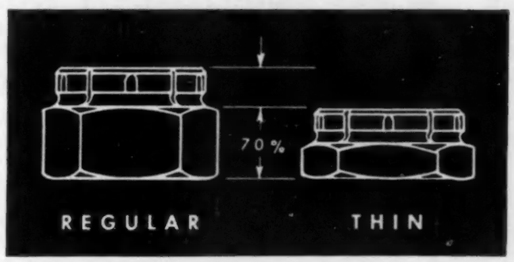
SPECIFICATIONS FLEXLOC THIN NUTS



NATIONAL COARSE THREAD—U.S.S

SIZE	A INCHES	H INCHES	WIDTH ACROSS CORNERS	WEIGHT PER 1000 NUTS
6-32	.312	.125	.361	1.8
8-32	.344	.172	.397	2.8
10-24	.375	.172	.433	3.3
1/4-20	.438	.203	.505	5.4
5/16-18	.563	.250	.649	11.6
3/8-16	.625	.265	.722	14.9
7/16-14	.750	.312	.866	24.9
1/2-13	.813	.312	.938	28.4
9/16-12	.875	.359	1.010	36.1
5/8-11	1.000	.391	1.155	54.1
3/4-10	1.125	.406	1.299	69.2
7/8-9	1.312	.469	1.516	107.5
1-8	1.500	.563	1.732	171.6
NATIONAL FINE THREAD—S.A.E.				
6-40	.312	.125	.361	1.8
8-36	.344	.172	.397	2.8
10-32	.375	.172	.433	3.3
1/4-28	.438	.203	.505	5.4
5/16-24	.500	.250	.577	8.7
3/8-24	.563	.266	.649	11.5
7/16-20	.625	.312	.722	14.9
1/2-20	.750	.312	.866	21.7
9/16-18	.875	.359	1.010	36.2
5/8-18	.938	.391	1.082	42.4
3/4-16	1.063	.406	1.227	54.5
7/8-14	1.250	.469	1.443	84.6
1-14	1.438	.563	1.660	136.3
1 1/8-12*	1.625	.625	1.876	193.5
1 1/4-12*	1.813	.750	2.093	296.0
1 3/8-12*	2.000	.812	2.309	389.0
1 1/2-12*	2.187	.875	2.526	498.0

*Steel only (plain or cadmium plated) in stock sizes.



FLEXLOC thin nuts are 30% lower than regular height locknuts. There is a corresponding saving in weight. In sizes through 5/16 in., thin FLEXLOCs meet tensile strength requirements for regular height locknuts. FLEXLOC nuts can be made in the thin type because every thread, even those in the locking section, carries its full share of the load. There are no nonmetallic inserts to waste head space or weaken the structure of the nut.

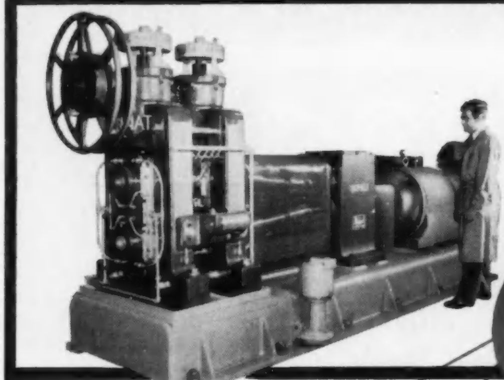
Standard FLEXLOC self-locking thin nuts are available in plain or cadmium plated alloy steel, for use in temperatures to 550°F; in plain or silver plated corrosion resisting steel, for temperatures to 750°F; and in brass and aluminum, for temperatures to 250°F.

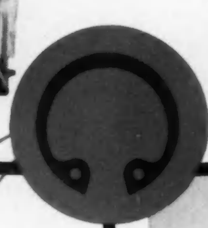
STANDARD PRESSED STEEL CO.

FLEXLOC® LOCKNUT DIVISION SPS

JENKINTOWN PENNSYLVANIA

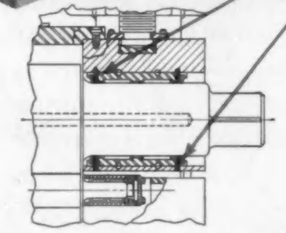
7-inch Waldes Truarc retaining rings cut costs, speed assembly-disassembly of 2-high/4-high mill





New Model TA-625 2-high/4-high combination rolling mill designed by Stanat Manufacturing Co., Long Island City, N. Y., reduces 2½" ingot to precision-rolled strip as thin as .001".

Waldes Truarc retaining rings help make possible a complete change of work rolls in 20 minutes...solve difficult problems of accuracy control by achieving positive location of bearings to extremely close tolerances. Rings eliminate costly parts and machining, save space, reduce maintenance.



In the assembly illustrated above, 7" Waldes Truarc (Series 5000) retaining rings—three on each roller—are used to position heavy-duty needle bearings in the bearing housing. Smaller rings position bearings in other roller assemblies and retain the shaft of a dual handwheel screwdown. All in all, 18 Waldes Truarc rings are used in the mill. They replace machined shoulders, spacers and lock nuts...eliminate costly threading, other machining operations.

Assembly is simple, even with giant 7" diameter Truarc ring. Special Truarc ratchet pliers grasp the ring securely, ease it into the groove, snap it securely into position. Smaller pliers and various high-speed assembly jigs are available for other rings, permit assembly-disassembly to be performed rapidly even by unskilled labor.

Whatever you make, there's a Waldes Truarc Retaining Ring designed to improve your product...to save you material, machining and labor costs. Quick and easy to assemble and disassemble, they do a better job of holding parts together. Truarc rings are precision-engineered and precision-made, quality controlled from raw material to finished ring.

36 functionally different types...as many as 97 different sizes within a type...5 metal specifications and 14 different finishes. Truarc rings are available from 90 stocking points throughout the U.S.A. and Canada.

More than 30 engineering-minded factory representatives and 700 field men are available to you on call. Send us your blueprints today...let our Truarc engineers help you solve design, assembly and production problems...without obligation.

For precision internal grooving and undercutting...Waldes Truarc Grooving Tool!

WALDES

TRUARC®

RETAINING RINGS

Waldes Kohinoor, Inc., 47-16 Austel Place, L.I.C. 1, N.Y.
Please send the new supplement No. 1 which brings Truarc Catalog RR 9-52 up to date.
(Please print)
Name ....
Title ....
Company ....
Business Address ....
City .... *Zone* .... *State* ....
SA 019

WALDES TRUARC Retaining Rings, Grooving Tools, Pliers, Applicators and Dispensers are protected by one or more of the following U. S. Patents: 2,382,948; 2,411,426; 2,411,761; 2,416,852; 2,420,921; 2,428,341; 2,439,785; 2,441,846; 2,455,165; 2,483,379; 2,483,380; 2,483,383; 2,487,802; 2,487,803; 2,491,306; 2,491,310; 2,509,081; 2,544,631; 2,546,616; 2,547,263; 2,558,704; 2,574,034; 2,577,319; 2,595,787, and other U. S. Patents pending. Equal patent protection established in foreign countries.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Inserto
the WONDER INSERT
It's Magic!
INSTALLATION
IS SIMPLE AND RAPID WITH THE ROSÁN "HEX-BAR"
ROSÁN Inserto
ALSO ROSÁN RING-LOCKED SELF-TAPPING STUDS AND INSERTS
U.S.A. AND FOREIGN PATENTS GRANTED AND PENDING
REPLACEMENT INSERT
FULL THREADS
Make your own replacement insert. Truncate ONE LESS thread of the replacement insert than the number of truncated threads found on the insert removed. This can be done by grinding or machining. Replacement inserts may also be purchased from Rosán Inc.
FULL THREADS
TRUNCATED THREADS
Inserto
SELF-TAPPING INSERT CAN BE DRIVEN IN A DRILLED HOLE OR A CLASS 3 TAPPED HOLE
You lock it when You drive it!
SELF-TAPPING
FOR ALUMINUM ALLOY, MAGNESIUM ALLOY, PLASTICS, BRASS, ETC.
STANDARD THREADS
EASY TO INSTALL, SIMPLE TO REMOVE
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NEWPORT BEACH, CALIFORNIA
BRANCH OFFICES: Los Angeles • Detroit • Dayton
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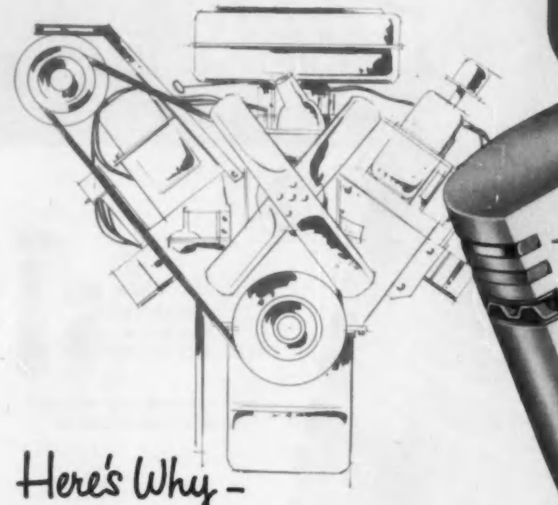
CANADA: Railway and Power Engineering Corp. Ltd.

Specify Muskegon design for '58 and '59



Here's Why –

Muskegon—producer of the piston rings used in more than one out of every three new cars—offers these important advantages for your 1958-59 plans:

ENGINEERING ABILITY: Muskegon's engineers design and develop all types of piston rings to meet exact requirements of every piston groove for any model of any engine. This precise engineering is why more than one out of every three new cars is equipped with Muskegon piston rings—all the way.

EXPERIENCE: You benefit from Muskegon's vast knowledge . . . experience gained from pioneering piston ring firsts, such as "Unitized" steel oil rings, chrome plated "Unitized" oil rings, sintered powdered metal rings and lapped chromium plated steel segments.

COOPERATION: Muskegon works closely with your engineers in the evolution of rings for all applications, including engines, transmissions, power steering and air compressors...ring designs that are worthy of the expense and time you put into new developments.

FACILITIES: Muskegon has the manpower and the facilities to give you bulk quantities of piston rings when you need them. Muskegon rings are also available in ready-packaged sets, with your own label, for your service shop requirements.

This is why you should seriously consider Muskegon design—exclusively—for '58 and '59.

MUSKEGON Piston Rings

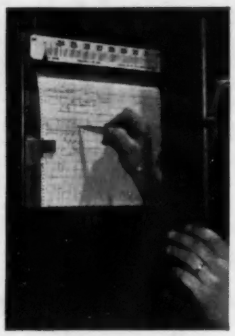
MUSKEGON PISTON RING CO.
MUSKEGON, MICHIGAN
PLANTS AT MUSKEGON AND SPARTA

DETROIT OFFICE:
521 New Center Bldg.
Telephone: Trinity 2-2113

Since 1921... The engine builders' source!

AFFILIATE: *Rotary Seal Division, manufacturers of mechanical seals for rotating shafts since 1931. Plants at Chicago, Illinois and Sparta, Michigan*

How Great Lakes Steel *charts* quality



Left: Thermocouple is inserted into an open-hearth furnace to check temperature of heat. Right: Multiple indicator records open-hearth temperature.

This view shows 12 of Great Lakes 17 open-hearth furnaces. Bright spots are furnaces being charged with pig-iron and scrap. The open-hearth process takes from 10 to 12 hours.

This is the business end of a thermocouple, the rugged yet delicately accurate device that measures temperature in an open-hearth furnace. The two fine wires you see above, inside the casing, absorb heat and transmit it as an electrical current to be charted by recording potentiometers.

No chance for guesswork here—through eleven long hours the rising temperature of what will be 500 tons of Great Lakes open-hearth steel is meticulously controlled. Then, at exactly the right time and the right temperature, the glowing molten metal gushes into ladles for pouring into ingots.

The slender, spidery lines on the chart assure another heat of high and uniform quality steel. Quality that is checked and rechecked at every step to assure that customer specifications are met precisely.

Why don't we get together and talk over your steel needs? Some time soon?

GREAT LAKES STEEL CORPORATION

Detroit 29, Michigan • A Unit of

NATIONAL STEEL CORPORATION

District Sales Offices: Boston, Chicago, Cincinnati, Cleveland, Grand Rapids, Houston, Indianapolis, Lansing, Los Angeles, New York City, Philadelphia, Pittsburgh, Rochester, St. Louis, San Francisco, Toledo, Toronto.

NEW

Tachometer Take-Off

...for VEEDER-ROOT Rev-Counters

With this new attachment, Veeder-Root Rev-Counters can be installed on any engine having a tachometer take-off in a position which is readily accessible for easy reading. Take-off can be furnished to suit average engine-speed.

So now you can make it easier than ever for your customers to see that your product is performing up to its guarantee . . . to see when routine maintenance is coming due, and whether servicing is needed.

You can count on Veeder-Root to figure out how to engineer these adaptable Rev-Counters into *your* products . . . not only engines, but generators, compressors, heaters, refrigerators, and what have you? Write:

Everyone... Can Count on

VEEDER-ROOT

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WITH

...an internal thermal gradient of 1.2° C/watt or less!

Industry's Highest Power Transistors

Large area, thinness and intimacy of collector contact with large copper base provide the efficient thermal transfer.

Result—an unusually cool collector junction in the Delco Radio alloy-type germanium PNP power transistor. The Delco Radio 2N173 and 2N174 transistors not only have high power handling ability but also low distortion characteristics. Thus, they are ideal for audio as well as your general power applications.

Furthermore, these transistors are normalized to retain their performance characteristics regardless of age. Write for engineering data. Delco Radio transistors are produced by the thousands every day.

TYPICAL CHARACTERISTICS

	2N173	2N174	
Properties (25°C)	12 Volts	28 Volts	
Maximum current	12	12	amps
Maximum collector voltage	60	80	volts
Saturation voltage (12 amp.)	0.7	0.7	volts
Power gain (Class A, 10 watts)	38	38	db
Alpha cutoff frequency	0.4	0.4	Mc
Power dissipation	55	55	watts
Thermal gradient from junction to mounting base	1.2°	1.2°	°C/watt
Distortion (Class A, 10 watts)	5%	5%	

DELCO RADIO DIVISION OF GENERAL MOTORS KOKOMO, INDIANA

DANA CORPORATION

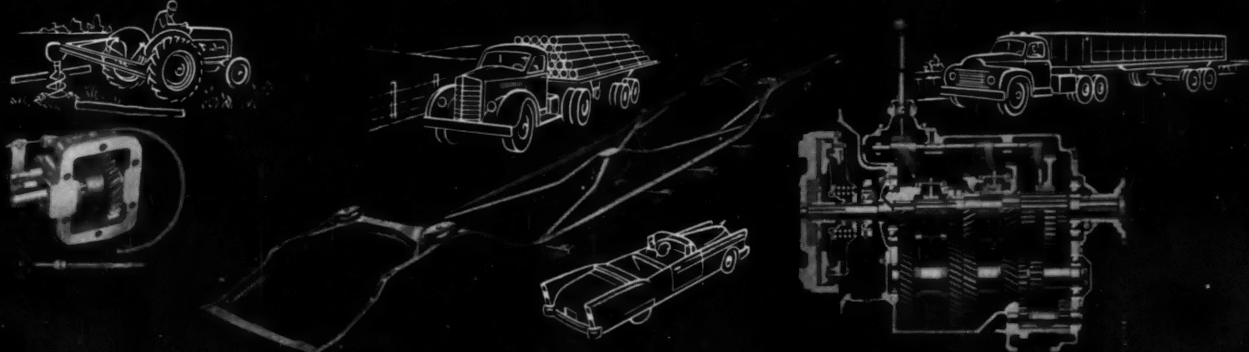
when you plan with DANA

Consistently . . . year after year for over a half-century . . . Dana has built up a rich fund of knowledge and skill in automotive power transmission and chassis design.

Dana service is complete and comprehensive. It creates . . . engineers . . . manufactures. It is a service that has produced millions of Spicer units for a majority of the manufacturers of automobiles, trucks, buses and tractors.

No matter what type of automotive vehicle you make . . . no matter what type of power transmission or chassis design you require . . . Dana engineers and resources can serve you well.

DANA will be at the **ROAD SHOW**



Toledo 1, Ohio

SPICER PRODUCTS: Transmissions • Universal Joints • Propeller Shafts • Axles • Torque Converters • Gear Boxes • Power Take-Offs • Power Take-Off Joints • Rail Car Drives • Railway Generator Drives • Stampings • Spicer and Auburn Clutches • Parish Frames • Spicer Frames

'57 Dodge Truck engine to use newly-designed Holley Distributor

First installation of the Rotovance Distributor (above) and Holley Governor (at right) will be on 1957 Dodge Truck models equipped with 354 engines. Two governors are used when the 354 engine is equipped with dual carburetion.

The first basic distributor design change in over two decades — Holley's new Rotovance Distributor and sandwich governor assembly — is standard equipment on the 354 cu. in. Dodge Truck engine for 1957. This distributor-governor combination is the first to locate control valve and advance mechanisms in a single housing.

The Rotovance Distributor and governor systems provide positive, consistent engine speed control — without power loss — with much better regulation than ordinary governors, from cut off to load point. Also standard on all Dodge Trucks equipped with Rotovance Distributors: Holley Ventilated Contact Sets. These unique center-vent points have proven in the laboratory and field alike to have a service life expectancy several times that of present contact sets.

See the new Holley Rotovance Distributor with sandwich governor at your nearby Dodge Truck dealer. It's one of the many advanced-design features which help give new "K" Series Dodge Trucks greater power and increased engine performance for 1957.

HOLLEY Carburetor Co.

11955 E. NINE MILE ROAD
VAN DYKE, MICHIGAN

FOR MORE THAN HALF-A-CENTURY—
ORIGINAL EQUIPMENT MANUFACTURERS
FOR THE AUTOMOTIVE INDUSTRY


MERCURY
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ESTABLISHED GALION 1907
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LOCKHEED
CARDWELL
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MOLINE TOOL CO. MOLINE, ILLINOIS
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EIMCO
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TRADE CHAMPION MARK
TWIN DISC
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BENDIX-WESTINGHOUSE AIR BRAKES
UNION PACIFIC RAILROAD
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if you use or plan to use

STEEL CASTINGS...

Take a good look at sources for steel castings. Can they adequately supply your needs now—and in the future? How about their other customers—when demands are high do you come first, second—or where? Are they "up" on quality control—do they have extensive production facilities—can they manufacture at lowest possible cost?

Take a look at Campbell, Wyant, and Cannon. Here is a foundry that can produce over 150 tons of steel castings a day . . . that can take care of your requirements and those of many others today and tomorrow. Modern equipment and complete facilities make it possible to economically cast steel in limited quantities or volume —in a variety of sizes and shapes. And no other foundry can surpass CWC's abilities in quality control. For example, CWC is the first foundry to employ the spectrographic analysis of metals—an important time and cost saving method. Castings are radiographed by a million volt x-ray to assure adherence to the most stringent specifications. Extensive heat treating facilities are available to provide required metallurgical structures. A research foundry helps to decide many things before actual production starts. These, and many other control measures, enable CWC to make steel castings of highest quality at low cost.

So take a good look at Campbell, Wyant and Cannon. Talk over your steel casting requirements with a CWC engineer now. Phone us at Muskegon 3-1331 or write:

Radiographing by million volt x-ray is one of many important CWC controls.

campbell, wyant and cannon

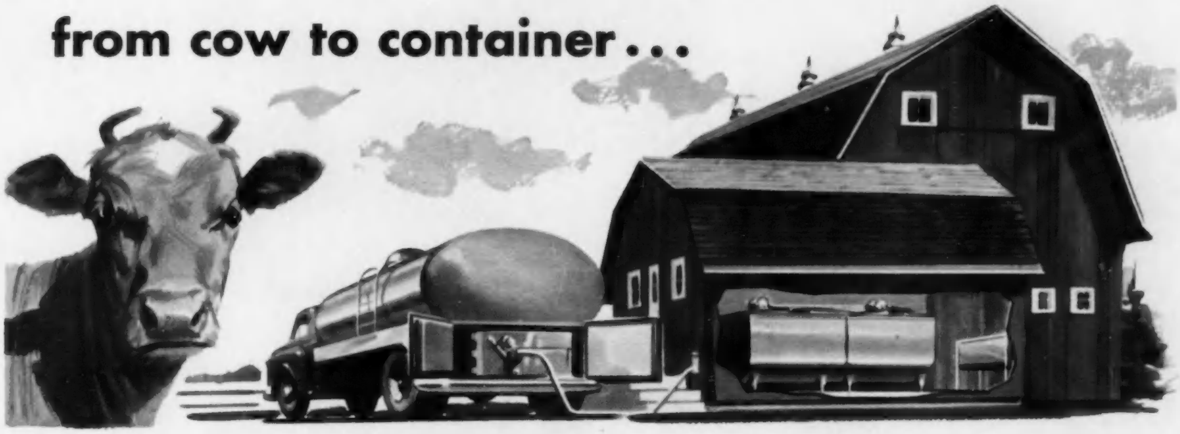
CWC

FOUNDRY COMPANY
DIVISION OF TEXTRON INC.
Muskegon, Michigan

SIX FOUNDRIES LOCATED IN MUSKEGON, LANSING AND SOUTH HAVEN, MICHIGAN...
PRODUCING STEEL, GREY IRON AND IRON ALLOY CASTINGS...READY TO SERVE YOU.

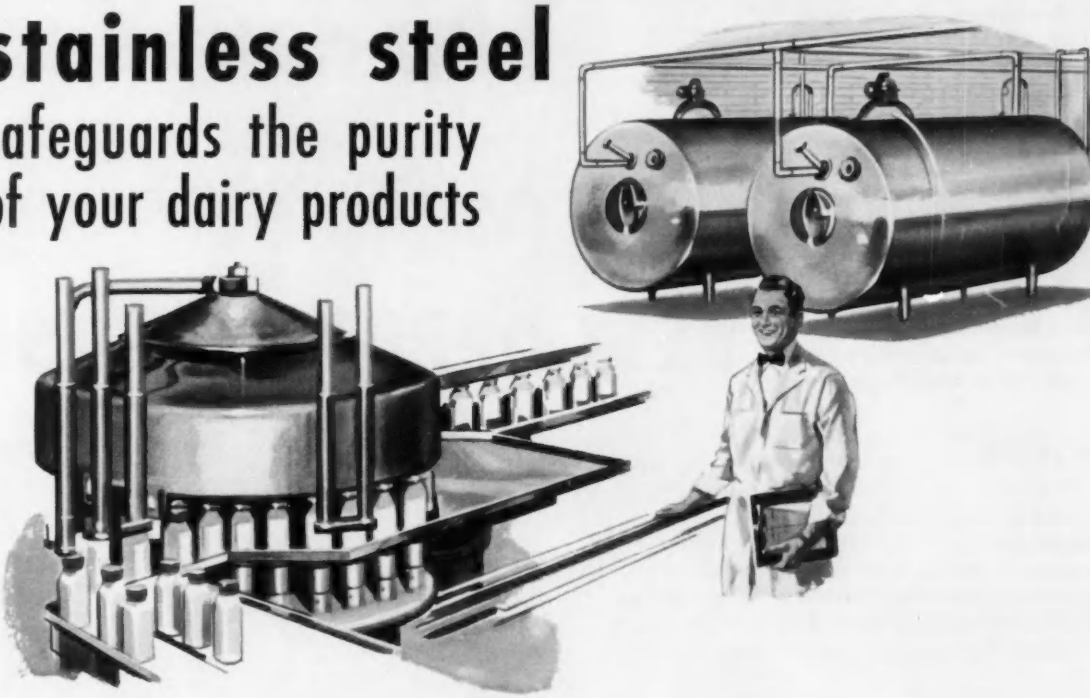

US RUBBER
PowerGrip "TIMING" BELTS

from cow to container...



stainless steel

safeguards the purity of your dairy products



Dairymen and milk-product plant operators know that Stainless Steel is the only metal that year after year effectively resists acid corrosion. It can easily be kept clean and sterile and imparts no odor in contact with the product.

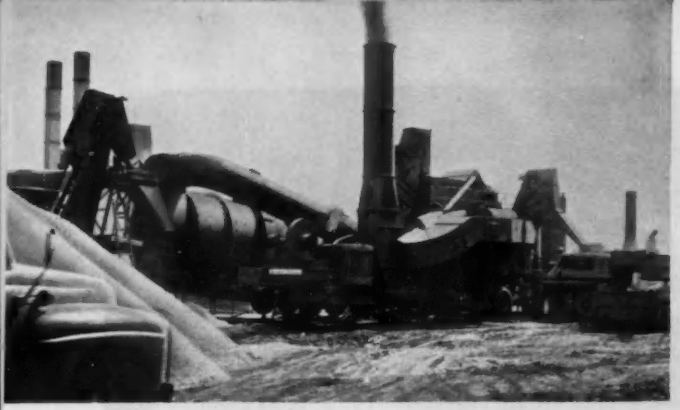
Through all the stages of milking, transportation, processing and packaging Stainless Steel completely safeguards the delicate flavor and highly sensitive qualities of milk and cream, and milk products like butter, cheese, ice cream and powdered milk.

The delicious taste of your dairy products and the assurance of their purity is due to the dairyman's extreme care and scientific methods and the use of Stainless Steel equipment.

McLouth Stainless Steel

For the product you make today and the product you plan for tomorrow specify McLouth high quality sheet and strip Stainless Steel

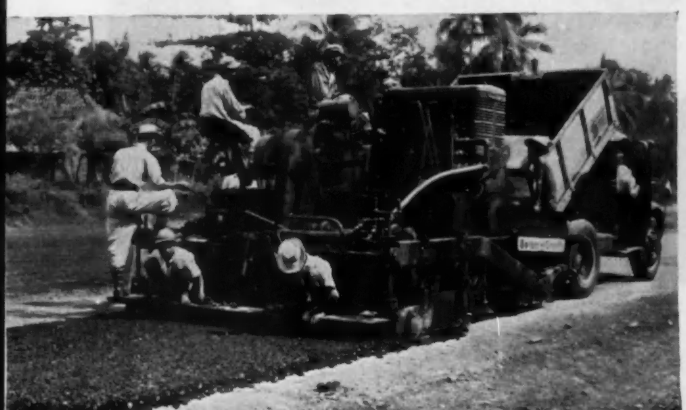
McLouth Steel Corporation DETROIT, MICHIGAN • MANUFACTURERS OF STAINLESS AND CARBON STEELS



An International UD-18A powers the cyclone dust collector and a UD-1091 operates the dryer in this Barber-Greene Model 848 bituminous plant owned by Hallet Construction Company, Ames, Iowa.

Rock County, Wisconsin, is now in the paving business with this Barber-Greene Model 848 Travel plant. Towing loader uses an International UD-350 and the mixer uses a UD-18A.

100% International power units and trucks is the rule for Hazelmore Bituminous Co., Fairmont, Minn. Their Barber-Greene Model 848 continuous-mix plant is powered by a UD-18A and a UD-24.



...WHY specify International® Power Units for bituminous plants?

These owners of Barber-Greene bituminous plants and pavers would give you these hard dollar reasons: Internationals have more features that pay off in lower production costs—and unsurpassed parts and service support for your convenience.

Economical? You bet, with a clean-burning exclusive injection and combustion system...a 45° angle of injection...new open-face single-orifice nozzles that give thousands of hours of coke-free operation.

Weather-proof? Definitely, with seconds-fast all-weather gasoline-conversion starting...full-flow filtering of all fuel, lube oil and air.

Dependable? Sure thing, with such features as tocco hardened crankshaft journals, precision insert bearings and replaceable hardened sleeves.

Heavy-duty? That's the only type of engine International has built in 55 years. And the positive-type valve rotators that make valve grinding such an infrequent need is just one of the famous IH long life features that have helped sell more than 400,000 diesels.

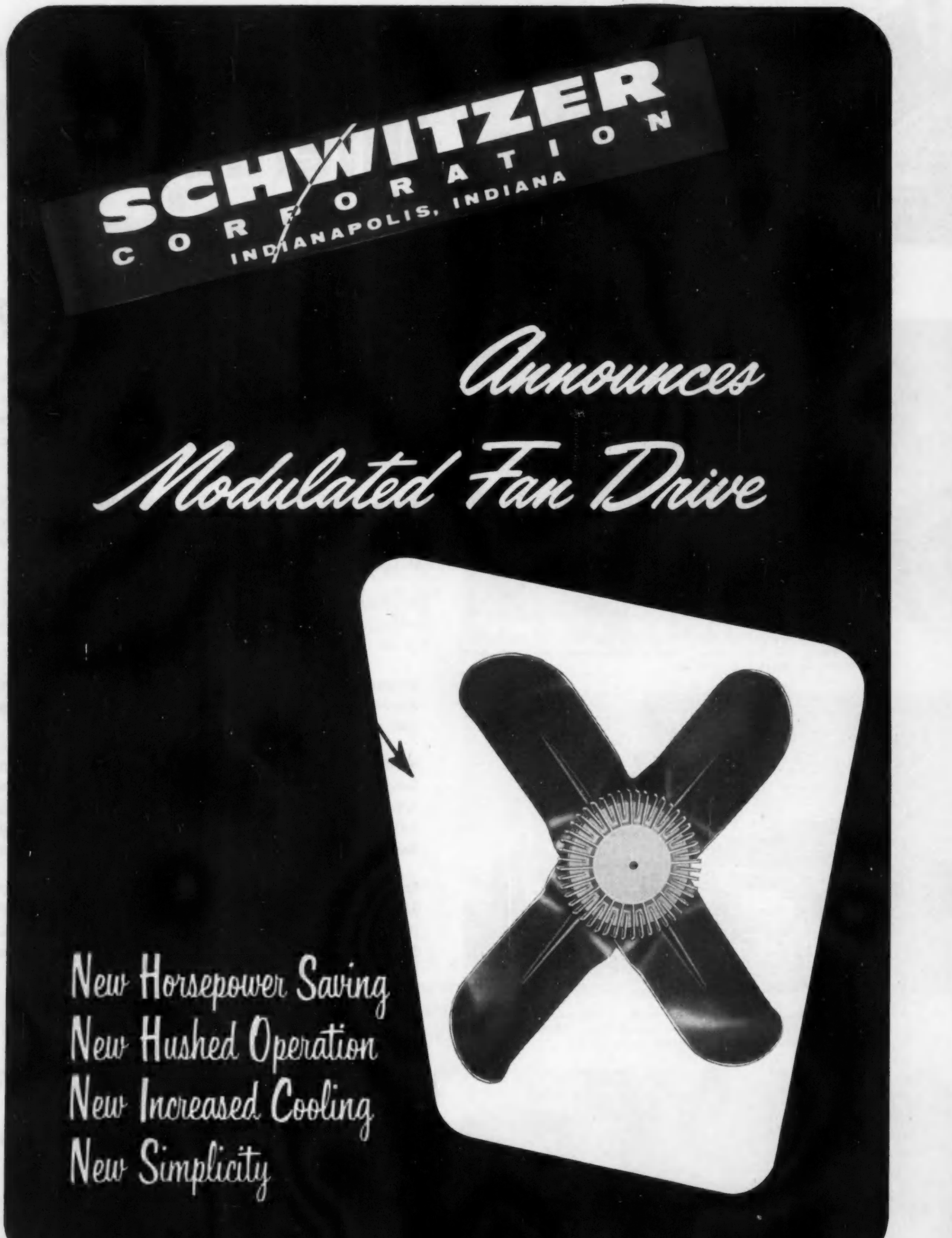
For more information, just see your easy-to-locate International Power Unit Distributor or Dealer. He'll provide proof you can specify and get an adaptable International power unit that's exactly right for your new or used machine. So be sure of profitable power for a long time to come by specifying Internationals for all of your driven machines.

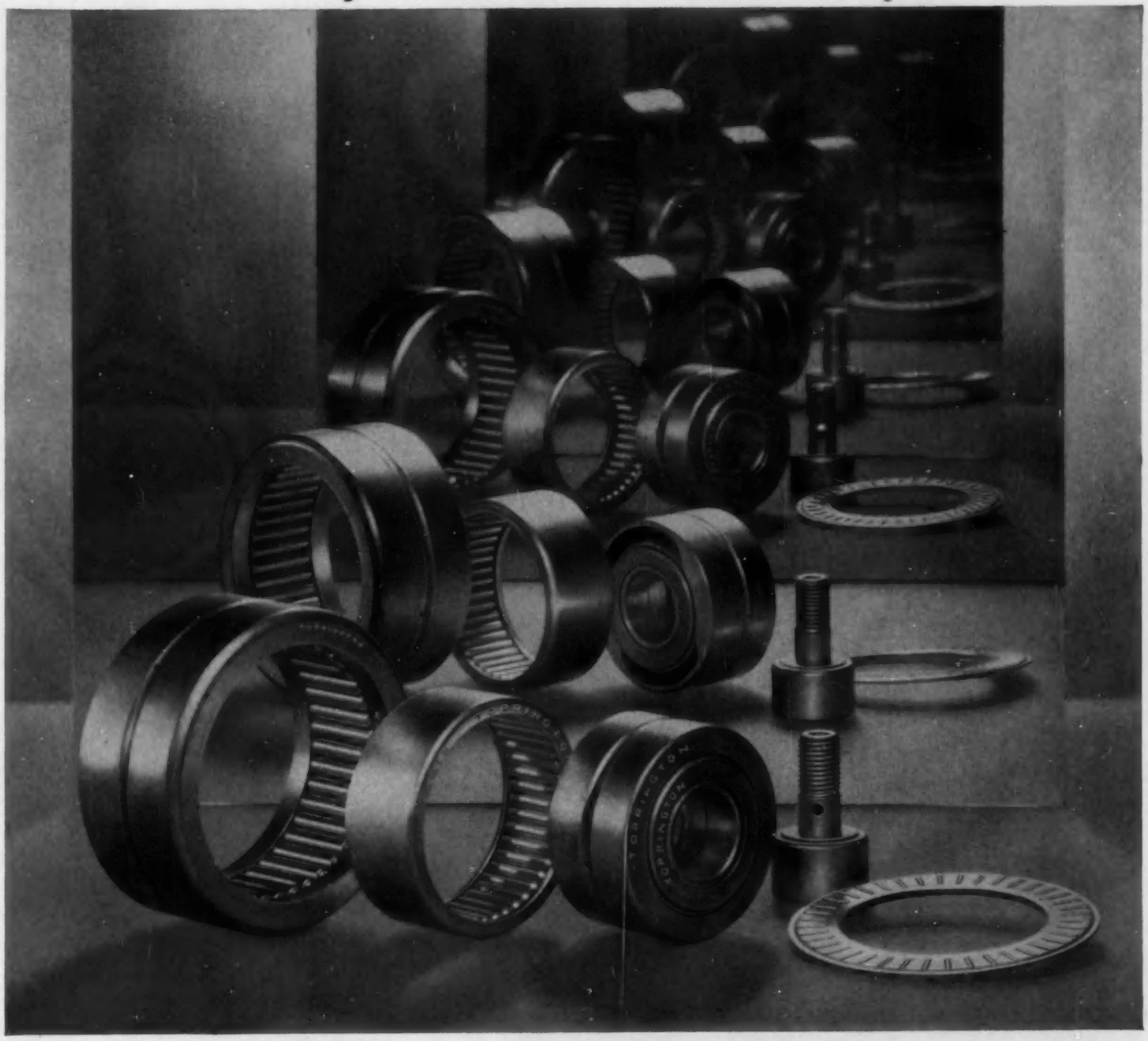
Even in Djakarta, Indonesia, the preference is for International power units. Here a UD-6 powers the government-owned Barber-Greene Model 879-A Finisher.

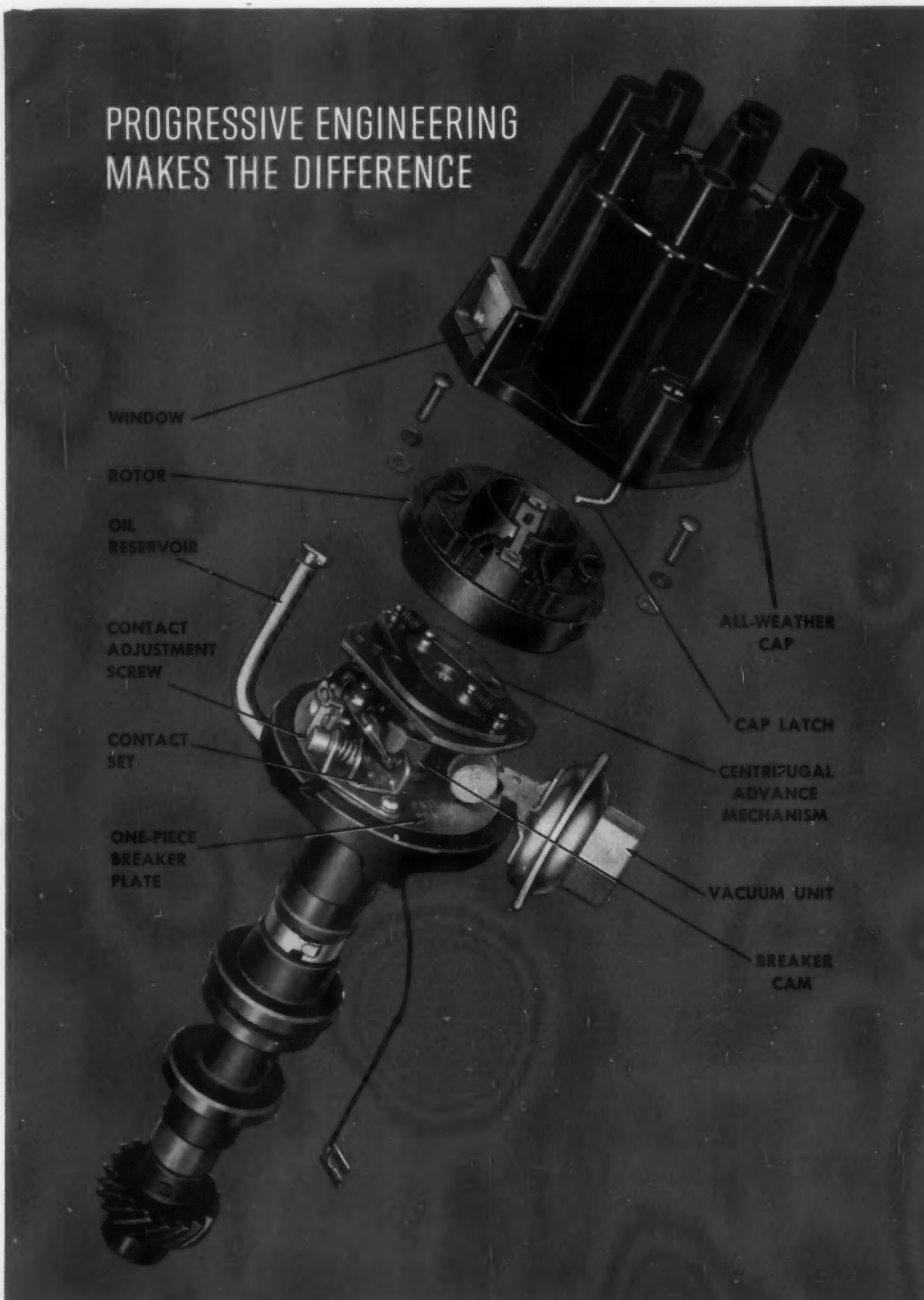
INTERNATIONAL® CONSTRUCTION EQUIPMENT

International Harvester Co., 180 N. Michigan Avenue, Chicago 1, Illinois

A COMPLETE POWER PACKAGE INCLUDING: Crawler, Wheel, and Side-Boom Tractors... Self-Propelled Scrapers and Bottom-Dumps... Crawler and Rubber-Tired Loaders... Off-Highway Trucks... Diesel and Carbureted Engines... Motor Trucks.


SCHWITZER
CORPORATION
INDIANAPOLIS, INDIANA
Announces
Modulated Fan Drive
New Horsepower Saving
New Hushed Operation
New Increased Cooling
New Simplicity


TORRINGTON


PROGRESSIVE ENGINEERING
MAKES THE DIFFERENCE
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ROTOR
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ADJUSTMENT
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ONE-PIECE
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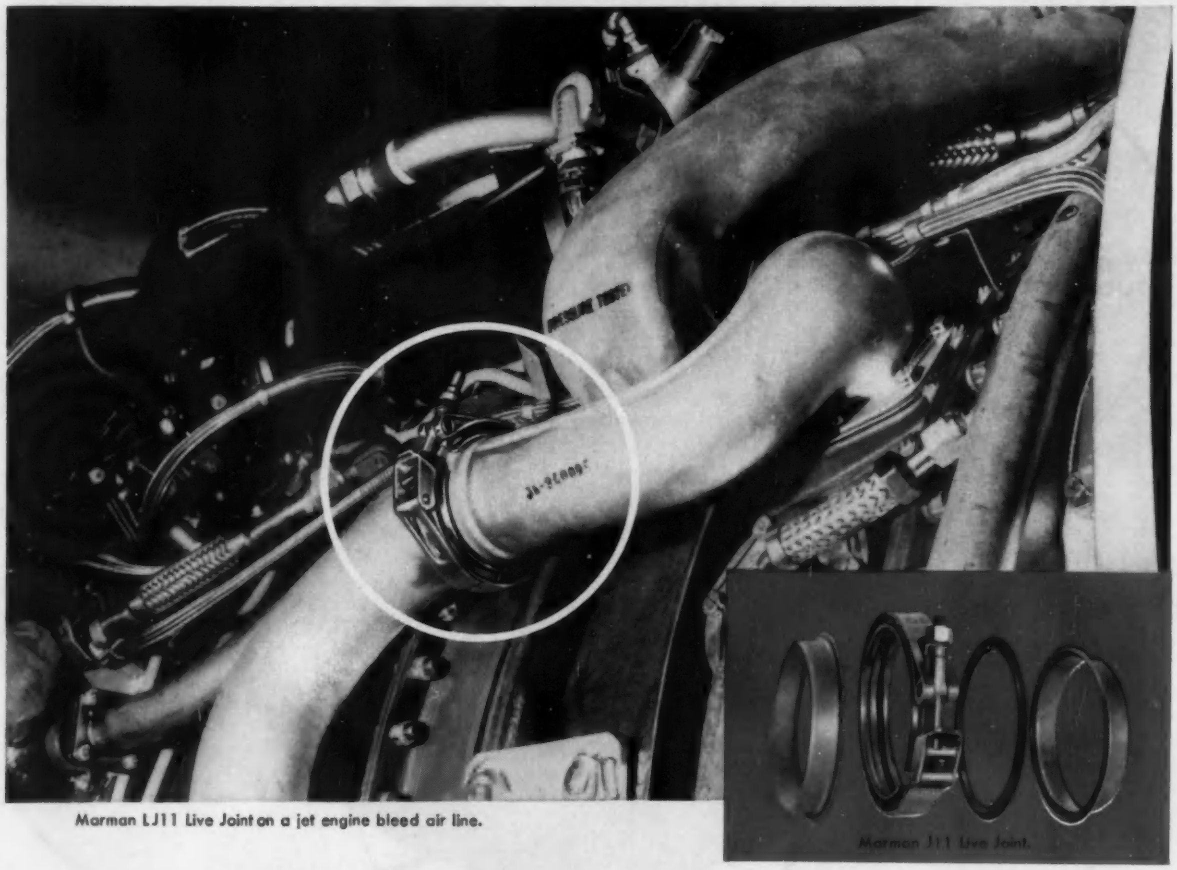
Marman LIVE Joint Systems Speed Connection-Disconnection of Aircraft Tubing



Marman LJ11 Live Joint on a jet engine bleed air line.

Marman J11 Live Joint.

Marman J11 and LJ11 Live Joints are designed to connect AND10104 tubing and maintain a positive seal over a wide range of temperatures and pressures. When deflections are imposed on the joint by pressure loads or thermal stresses, the wedging action of the V-band coupling against the flange faces retain the metal-to-metal seal.

Compact configuration of high performance Marman Live Joints make them superior to bolted flanges and B-nuts where installation accessibility and weight savings are desired. J11 and LJ11 Joints are available in O.D. tube sizes from 1" to 12". Temperature range is —300°F. to —1000°F., for pressures up to 2000 psi. Write for full information.

MARMAN PRODUCTS COMPANY, INC.

A SUBSIDIARY OF Aeroquip CORPORATION

11214 EXPOSITION BLVD., LOS ANGELES, CALIFORNIA

IN CANADA: AEROQUIP (CANADA) LTD., TORONTO 15, ONTARIO

MARMAN PRODUCTS ARE MANUFACTURED UNDER VARIOUS U.S., CANADIAN AND FOREIGN PATENTS AND OTHER PATENTS PENDING

Proved Dependable!

that's why Aeroquip Hose Lines and Self-Sealing Couplings are the most widely used in the Aircraft Industry

It's no wonder the aircraft industry readily turns to Aeroquip for the answers to fluid line design, maintenance and service problems.

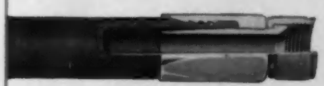
Aeroquip Products are skillfully engineered to perform as specified under all operation conditions.

Aeroquip quality standards, highest in the industry, are always maintained.

Aeroquip offers a highly trained, highly successful engineering team that is available to all airframe and engine manufacturers for engineering assistance.

To the aircraft industry, Aeroquip means *dependability.* Write for Aircraft Product Catalog No. 101.

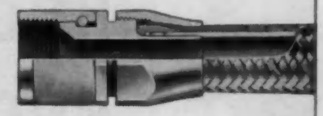
For 3000 psi. Hydraulic and Pneumatic Lines



use Aeroquip 680 Hose Assemblies. Designed for fluid systems up to 3000 psi. and operating temperatures from —65° to +200° F. In sizes from ¼" to 1".

666 Teflon Hose and *"super gem"* Fittings

for high temperature fluid applications. Designed for any aircraft fluid system with operating temperatures up to 500° F. and pressures up to 1500 psi. In sizes from 3/16" to 1".

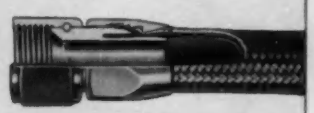


For Hydraulic, Lube Oil, Fuel, Coolant Lines

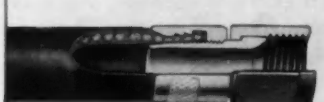
use Aeroquip 350, 360 and 390A Hose Assemblies. Designed for fluid systems from 200 to 3000 psi. and operating temperatures from —65° to +275° F. In sizes from 3/16" to 3".

601 Lightweight Engine Hose and *"little gem"* Fittings

for all weight-saving engine applications. Designed for use in fuel, petroleum, or synthetic lube oil and hydraulic systems up to 1500 psi. Operating temperatures from —65° to +300° F. In sizes from 3/16" to 2".



For Low-Pressure Air, Vacuum, Oil, Fuel Lines

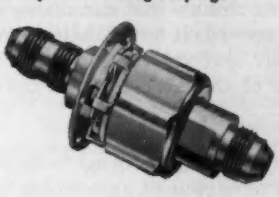


use Aeroquip 359 Hose Assemblies. Designed for low pressure systems up to 300 psi. and operating temperatures from —65° to +180° F. In sizes from ⅛" to ⅜".

617 Lightweight Airframe Hose and Fittings

for all weight-saving airframe applications. Designed for 125 psi. aircraft fuel and oil systems and vent and drain lines. Operating temperatures from —65° to +300° F. In sizes from 1" to 2".

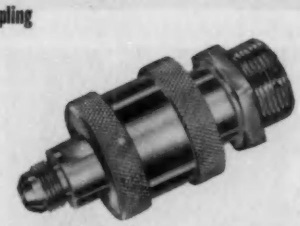
3000 psi. Self-Sealing Couplings



Use Aeroquip 155 and 145 Self-Sealing Couplings to speed inspection, servicing and replacement of power plant and other fluid system components. Lines can be connected and disconnected quickly, with no loss of fluid or inclusion of air. In sizes from ¼" to 1½".

New! Type 3200 Self-Sealing Coupling

for quick, positive connection and disconnection of 3000 psi. hydraulic systems, the Type 3200 Coupling is lightweight, simple and safe to operate. It connects with a quarter turn of the union nut and releases with an axial pull on the nut, with no stable intermediate position. In sizes from —4 to —16.



"little gem" and *"super gem"* are Aeroquip Trademarks

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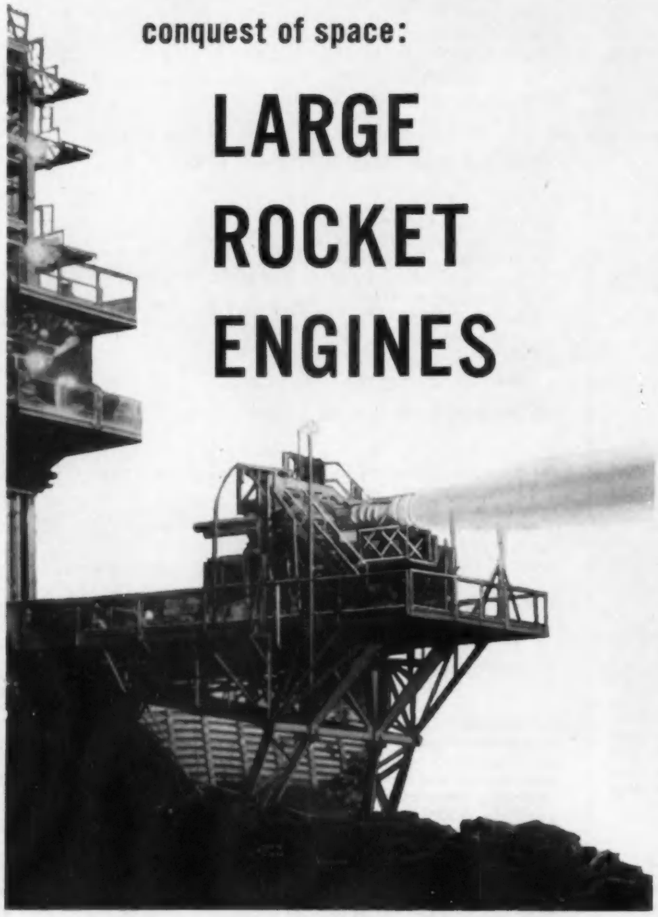
Wanted: Pioneers for man's last frontier

Help us build power for the conquest of space:

LARGE ROCKET ENGINES



Tomorrow's count down already fills the air at ROCKETDYNE'S 1,600-acre Field Test Laboratory in the Santa Susana Mountains near Los Angeles. For this is the free world's largest workshop for rocket engineering—the great new industry that is now attracting many of the finest scientific and engineering minds in the country.

EXACTING RESEARCH, EXCITING PROSPECTS

From the rock-bedded test stands come 2 miles of recordings per day—data far ahead of available texts. The big rocket engine is a flying chemical factory in an absolute state of automation. It tolerates no error. It demands ductwork, turbomachinery, pressure chambers, orifices, injectors, heat exchangers and closed-loop control systems that must put hundreds of pounds of precisely mixed propellants into controlled combustion every second. Tolerances go down to 0.0001″. Temperatures range from -250° F to 5000° F. Process time constants occur in "steady state conditions" of the order of a few milliseconds. Event sequences are minutely evaluated, as basis of designed performance predictions of extreme exactitude.

The methods now being developed at ROCKETDYNE for producing effective power to the limits of mechanical stress will have wide application. Such experience is practically unobtainable anywhere else. As a graduate engineer, *you* may be able to participate—now.

What motivates a rocket engineer? Well, the material advantages are high; but it is the work itself that draws him most. He feels the same incentive that moved Magellan . . . spurred the Wright Brothers . . . and beckoned again to Goddard as he flew the first liquid rocket at Auburn, Mass. in 1926.

At ROCKETDYNE, you can do this kind of pioneering in a management climate that stimulates personal growth—and rewards it to the limits of your ability. Academically, too, you can grow with our financial aid; some of the nation's finest universities are close by.

INTERESTING BOOKLET: "The Big Challenge"—facts on design criteria and development approaches used at ROCKETDYNE. Write for your personal copy, specifying your degree and years of post-college experience. Address: A. W. Jamieson, Engineering Personnel Dept.SAE,6633 Canoga Ave., Canoga Park, California.

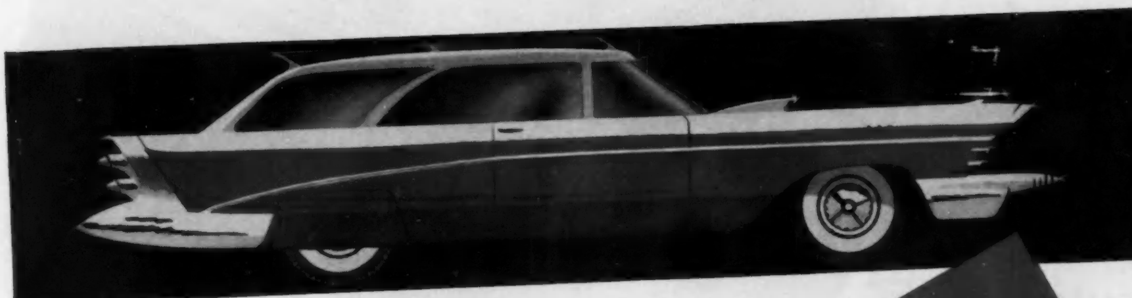
WILLIAM J. CECKA, JR., 35, aeronautical engineer, (Univ. of Minn. '43), was called from North American by the Air Force for experimental rocket work in 1944. On his return, he progressed rapidly: 1948, supervisory test job; 1950, group engineer, operations; 1953 engineering group leader; 1955, section chief of engineering test. Using our refund plan, he has his M.Sc. in sight.

GEORGE P. SUTTON, in the 13 brilliant years since receiving his MSME, Cal Tech, has made rocketry a way of life. His reputation is world wide. His book *Rocket Propulsion Elements* is recognized as the standard text on the subject. Still active academically, but no bookworm, he takes time off occasionally to study the laws of motion at some of the world's better ski resorts.

ROCKETDYNE

A Division of North American Aviation, Inc.

BUILDERS OF POWER FOR OUTER SPACE



moisture-free air for air brake systems

Wagner moisture ejection valve keeps reservoirs clean and dry—*automatically!*

Since moisture accumulation in the brake system can be a problem, you'll be interested in this fully automatic moisture ejection valve.

Operating at 15 to 20 p.s.i. pressure, it ejects moisture with each average brake application.

It mounts in any convenient location . . . no heating element is necessary as the valve cannot freeze in open (exhaust) position. It connects to the air system by two air lines—one leading from the bottom of the air reservoir and the other from a brake application line.

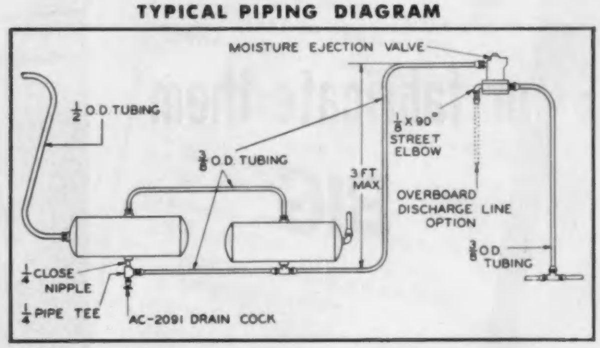
Expulsions occur without a noticeable drop in tank gauge pressure.

HIGH CAPACITY—valve can eject up to 4 fluid ounces at a time . . . even expels foreign particles which may have settled to the bottom of the tank.

CORROSION RESISTANT metal parts. Diaphragms are a combination of neoprene and nylon cord for long life and high resistance to oil.

OPEN TO ATMOSPHERE—valve fluid cavities are open to atmosphere . . . it is impossible to trap moisture within the unit. *Cannot balance in open position* . . . and "dump" reservoir pressure.

TYPICAL PIPING DIAGRAM



Wagner Air Brake Application Valves for Straight Air Systems

Actuating Arm Type **Treadle Type** **Basic Type**

These valves provide complete braking control for safe, sure stops. Each valve is completely interchangeable with other makes of valves. The basic valve can be installed by simply transferring the actuating mechanism to the Wagner valve. The treadle valve can be adjusted to angle properly with the contour of the floor board and also offers external adjustment of exhaust valve clearance.

For complete information on Wagner Air Brake Systems, write today for Catalog KU-201A.

K56-28

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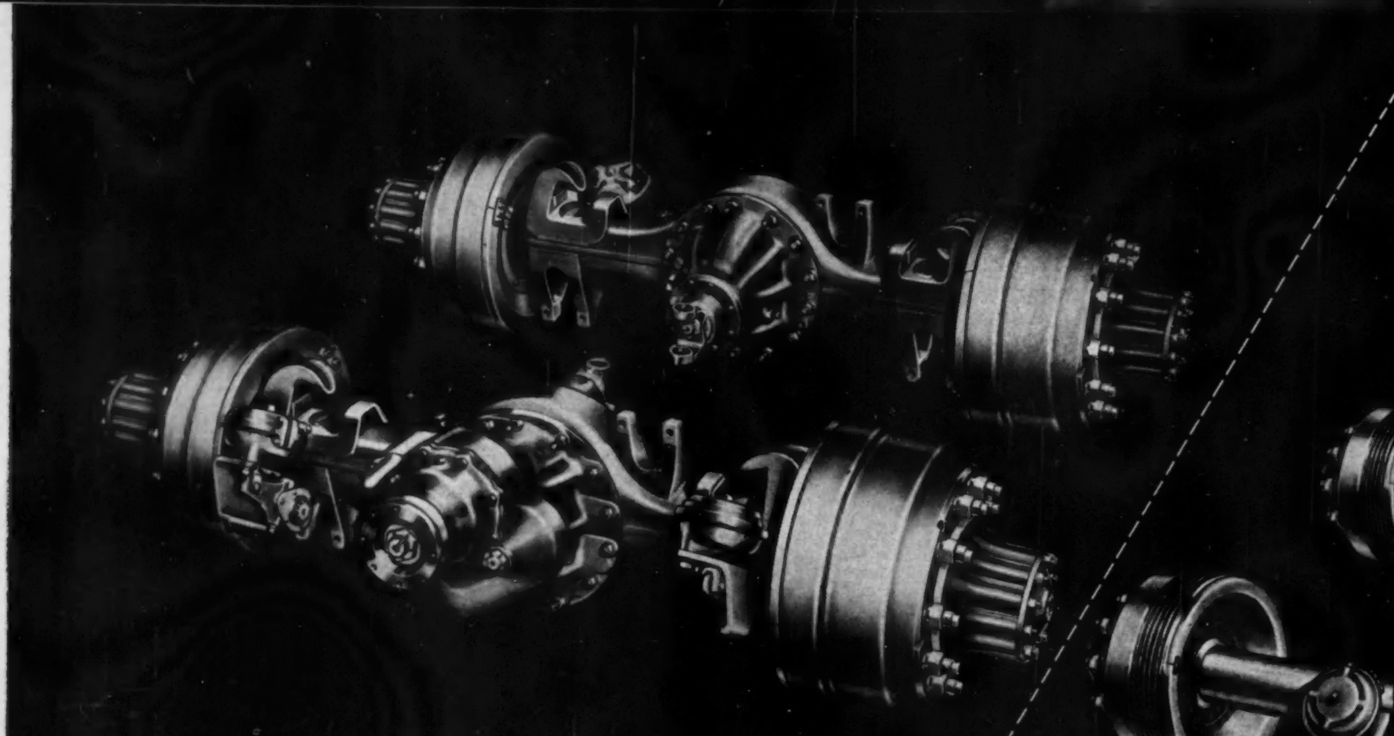

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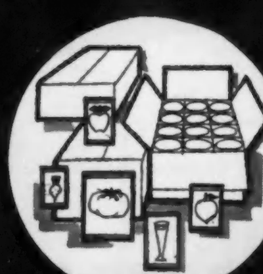
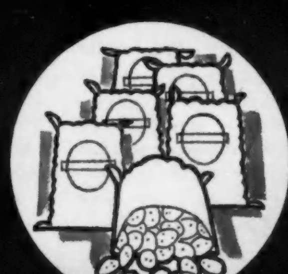
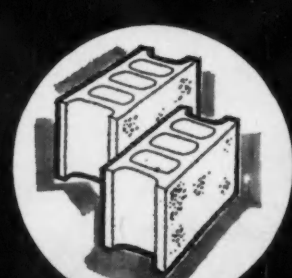


Haul 21 more cases of can goods, per load!

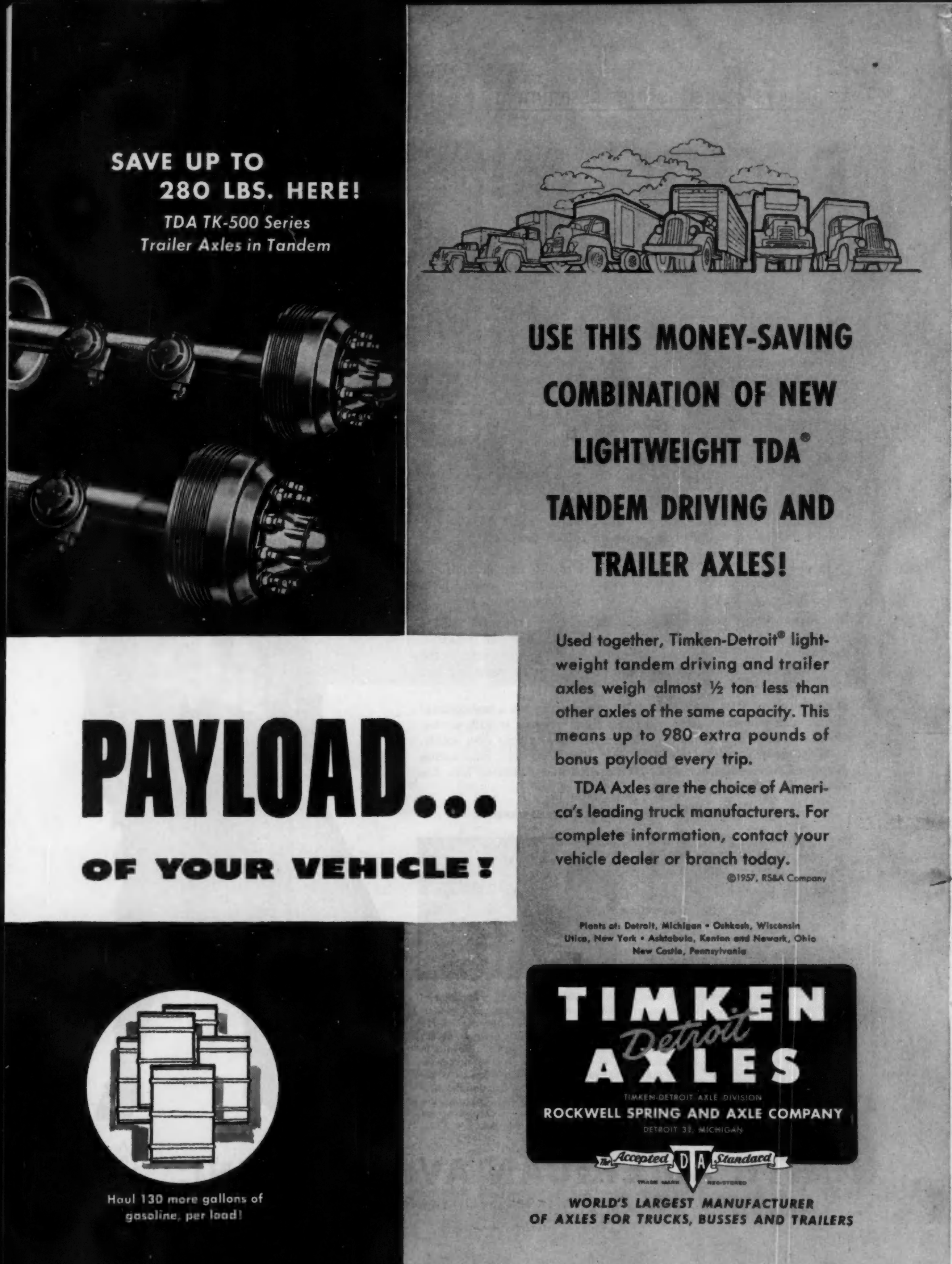


Haul 10 more bags of potatoes, per load!



Haul 30 more cinder blocks, per load!

Figure your extra profit, in terms of additional ton-miles of payload!



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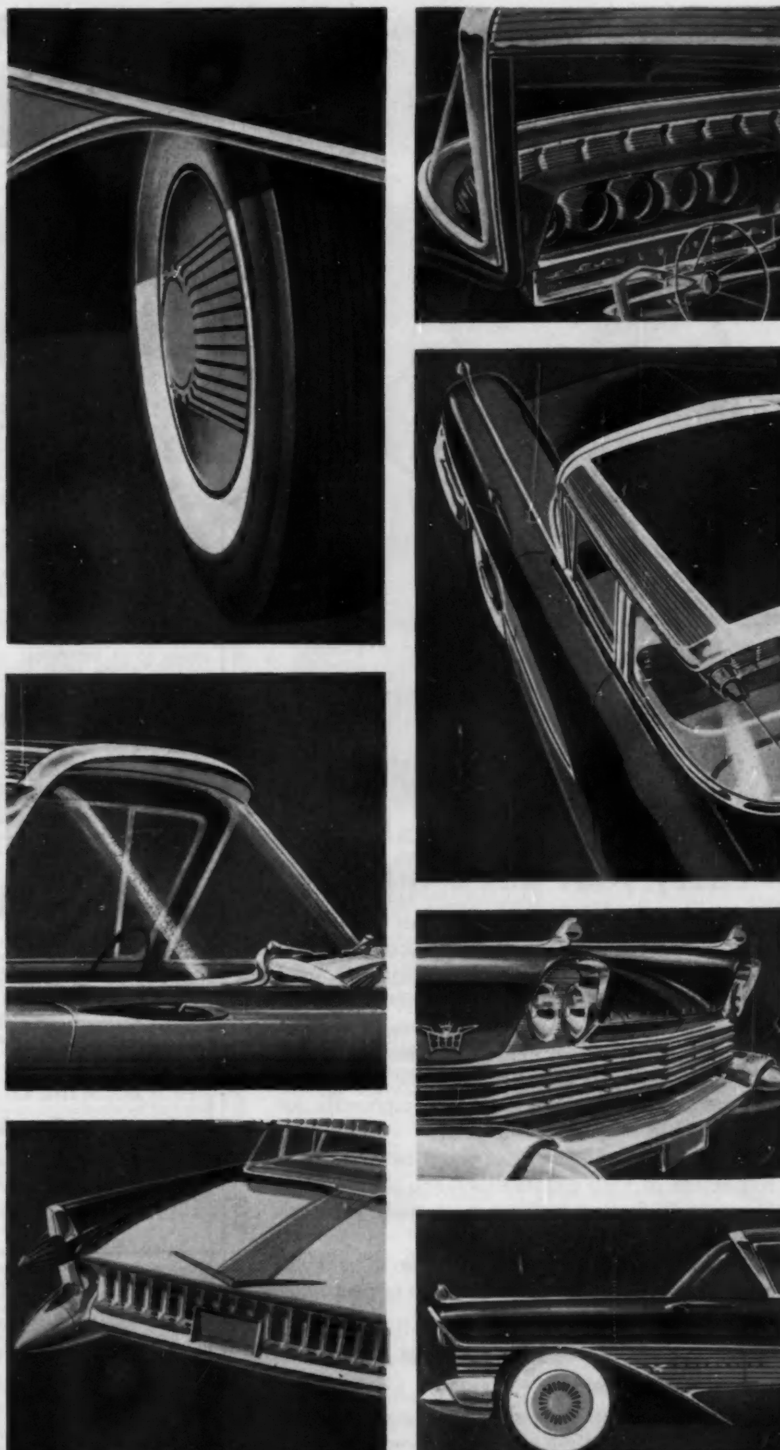

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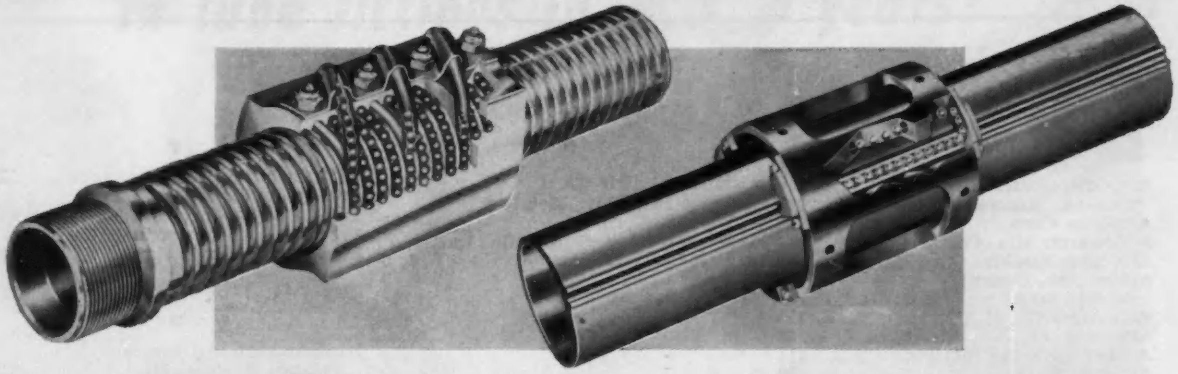
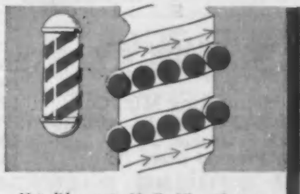
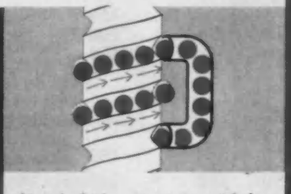


Saginaw b/b Screws guaranteed 90% efficient —offer 6 major advantages for designers

Available in custom machined and commercial rolled thread types — have been built from 1½ inches to 39½ feet long — ⅜ to 10 inches diameter.



Nut *glides* on steel balls. Like stripes on a barber pole, the balls travel toward end of nut through spiral "tunnel" formed by concave threads in both screw and mating nut.



At end of trip, one or more tubular guides lead balls diagonally back across outside of nut to starting point, forming closed circuit through which balls recirculate.

1 VITAL POWER SAVINGS. With guaranteed efficiency of 90%, Saginaw b/b Screws are up to 5 times as efficient as Acme screws, require only ⅕ as much torque. This permits much smaller motors with far less drain on the electrical system. Circuitry is greatly simplified.

2 SPACE/WEIGHT REDUCTION. Saginaw b/b Screws permit use of smaller motors and gear boxes; eliminate pumps, accumulators and piping required by hydraulics. In addition, Saginaw b/b Screws themselves are smaller and lighter. Units have been engineered from 1½ in. to 39½ ft. in length.

3 PRECISE POSITIONING. Machine-ground Saginaw b/b Screws offer a great advantage over hydraulics or pneumatics because a component can be positioned at a predetermined point with precision. Tolerances on position are held within .0006 in./ft. of travel.

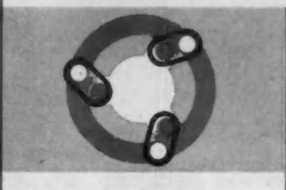
4 TEMPERATURE TOLERANCE. Normal operating range is from −75° to +275° F., but assemblies have been designed in selected materials which function efficiently as high as +900° F. These units are practical where hydraulic fluids have lost efficiency or reached their flash point.

5 LUBRICATION LATITUDE. Even if lubrication fails or cannot originally be provided because of extreme temperatures or other problems, Saginaw b/b Screws will still operate with remarkable efficiency. Saginaw units have been designed, built and qualified for operation without any lubrication.

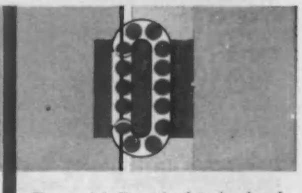
6 FAIL-SAFE PERFORMANCE. Far less vulnerable than hydraulics. In addition, Saginaw offers three significant advantages over other makes: (1) Gothic arch grooves eliminate dirt sensitivity, increase ball life; (2) yoke deflectors and (3) multiple circuits provide added assurance against operating failure.

Saginaw b/b Splines average 40 times lower friction coefficient than sliding splines

Transmit or restrain high torque loads far more efficiently—have been built from 3 inches to 10 feet long—⅜ inch to 6 inches in diameter.



The *Saginaw b/b Spline* radically increases the efficiency of transmitting or restraining high torque loads. Instead of *sliding* against each other, surfaces *glide* on rolling balls.



The steel balls recirculate in closed circuits formed by mating longitudinal raceways spaced around the circumference of inner and outer splines. Guides return balls.

This revolutionary new kind of spline utilizes the same basic principle pioneered by Saginaw in the ball/bearing screw.

It permits new engineering designs never before practical—literally lets you achieve the "impossible"! In any application where column length must change under torque load, the Saginaw b/b Spline offers greatly decreased friction, less wear, longer life, more dependable operation. It can be fitted with integral gears, clutch dogs, bearing and sprocket seats or a wide choice of other attachments for use with electric, hydraulic or pneumatic units. To convert push-pull to rotary motion, helical types are available with very high leads, ranging from 20:1 to 100:1.

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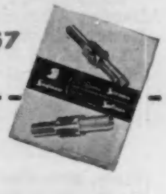

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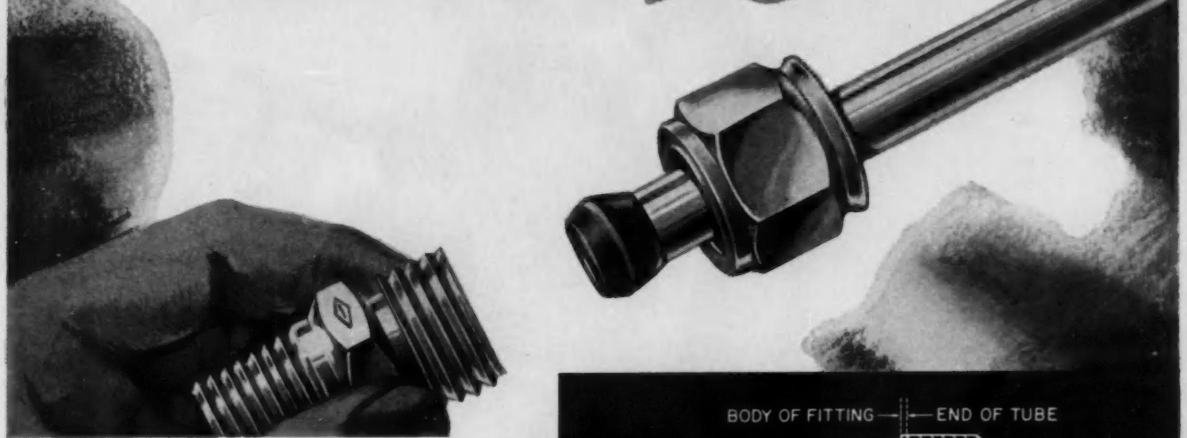

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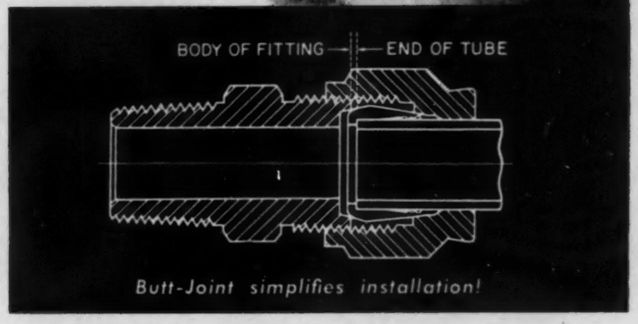

makes a positive butt-joint • no need to spring tubing • withstands higher pressures • foolproof assembly • no flaring or threading

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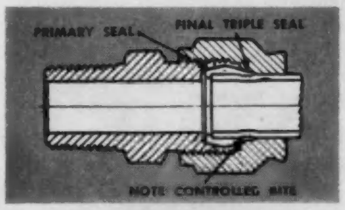
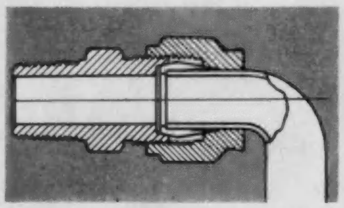
All this plus the fact that Hi-Seal fittings can be disconnected and reconnected as often as desired with assurance of original pressure-tight seal!

Conforms to **J.I.C.** Standards

Ask your Imperial distributor for full details on the Hi-Seal Fitting. Write for Bulletin 3061.



FOOLPROOF ASSEMBLY — Hi-Seal goes together only one way. No need to disassemble or double check for tightness.



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